MODIFICATION FOR TF2008 LOCK

TF 2171

# TF 2171

## Digital Synchronizer

INSTRUCTION MANUAL

MARCONI INSTRUMENTS

Instruction Manual

No. EB 2171

for

# Digital Synchronizer

# TF 2171

*Model No. 52171-900*

mi Technical Publications

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MARCONI INSTRUMENTS LIMITED
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Chapter 1

# General information

## 1.1 INTRODUCTION

Digital Synchronizer TF 2171 is designed for use with Signal Generator TF 2015, to which it can be fitted as shown in Fig. 1.1. Together, the instruments provide a 10 to 520 MHz signal generator system with high discrimination tuning and very good frequency stability.

Warm-up drift is eliminated, so measurements can be commenced almost immediately after switching on. Incremental frequency control can be obtained digitally by adjusting the frequency switches of the synchronizer in increments of 100 Hz up to a maximum of 0.5% of the initially set frequency without any readjustment of the generator.

The synchronizer can also be switched to provide a 1 MHz standard frequency or to accept an external 1 MHz frequency standard.

The setting up procedure is extremely simple and calls only for the positioning of the synchronizer frequency switches and the tuning of the signal generator to obtain a 'locked-on' condition which holds the frequency of the generator to within 2 parts in $10^7$ of the frequency indicated by the synchronizer.

All the features of Signal Generator TF 2015 are fully maintained including the a.m. and f.m. facilities and the synchronizer can be switched to allow the generator to be used independently i.e. in the unlocked mode.

*Fig. 1.1 Digital Synchronizer TF 2171 fitted below Signal Generator TF 2015*

## 1.2 DATA SUMMARY

| *Characteristic* | *Performance* |
|---|---|
| CARRIER FREQUENCY | |
| Range : | 10 MHz to 520 MHz. (Specifically for use with Signal Generator TF 2015.) |
| Selection : | Seven decade switch controls in 100 Hz steps. |
| Accuracy : (as measured over a period of ten seconds or greater) | After synchronization, frequency accuracy and stability is within 2 parts in $10^7$ of the value indicated on the decade controls. This is achieved after 10 min. (typically 5 min.) warm-up over an ambient temperature range of $0^{\circ}$ to $40^{\circ}$C. |
| Crystal aging : | ±1 part in $10^6$ per year. |
| RF INPUT | Compatible with counter output of Signal Generator TF 2015. |
| **Power requirements** | |
| AC supply : | Any voltage within the limits 95 V to 130 V and 190 V to 264 V; 45 Hz to 500 Hz. |
| Power consumption : | 30 VA. |

**Dimensions and weight**

| *Height* | *Width* | *Depth* | *Weight* |
|---|---|---|---|
| 140 mm (5.5 in) | 286 mm (11.25 in) | 311 mm (12.25 in) | 5.7 kg (12.5 lb) |

## 1.3 ACCESSORIES

Supplied

| Code No. | |
|---|---|
| 43129-071 | AC supply cable. |
| 43129-063 | Flexible coaxial cable, 50 Ω BNC plug to BNC plug. |
| 43129-064 | Semi-rigid coaxial cable, 50 Ω TNC plug to TNC plug. |
| 46883-214 | Mounting kit, for fitting to Signal Generator TF 2015. |

Available

| | |
|---|---|
| 41690-044 | Carrying case. |
| 43129-103 | Coaxial cable, 50 Ω TNC plug to BNC plug. |

Chapter 2

# Operation

## 2.1 FITTING TO SIGNAL GENERATOR

(1) Turn TF 2015 upside down and remove the bottom section of the case.

(2) Dismantle the tilt bar fitted at the front and discard the external plate with the two holes and two slots.

(3) Refit the tilt bar using one of the two latching plates supplied (joggled ends of plate inwards).

(4) Using the fixings supplied, fit the two plastic stands to clamp the latching plate.

(5) Remove the two rear stands and refit to clamp the second latching plate using existing fittings.

(6) Refit the bottom section of the case; then position TF 2015 on top of the synchronizer and clamp the two instruments together using the clips attached to each side of the synchronizer case.

## 2.2 CONNECTING TO SIGNAL GENERATOR

Only two connections, both at the rear, are required between the synchronizer and TF 2015.

(1) Using the flexible coaxial cable supplied, connect SYNC OUT on the synchronizer to SYNC/ SWEEP IN on TF 2015.

(2) Using the semi-rigid coaxial cable supplied, connect RF INPUT on the synchronizer to COUNTER OUT on TF 2015.

## 2.3 AC SUPPLY CABLE

The a.c. supply cable is fitted at one end with a female connector which mates with the a.c. input connector on the instrument. When fitting a supply plug ensure that the conductors are connected as follows :

| | |
|---|---|
| Earth | - Green/Yellow |
| Neutral | - Blue |
| Live | - Brown |

## 2.4 PRELIMINARY REQUIREMENTS

Prior to connecting the instrument to the a.c. supply :

(1) Check that the voltage selector switch is set to accept the local supply, i.e. set to 230 V for the range 190 to 264 V or to 110 V for the range 95 to 132 V. (Voltage regulation eliminates transformer tap changing except between the 95-130 V and 190-264 V ranges.)

To change the range, remove the locking plate, set the switch correctly, reverse the plate and refit.

(2) Check that the fuse is of the correct rating and type - see Section 2.5 - and secure in its holder.

## 2.5 FUSE

The instrument is normally supplied with a fuse rated at 160 mA (slow-blow) and with the mains selector switch set for supply voltages of 190 to 264 V.

For supply voltages of 95 to 130 V change the fuse for one rated at 250 mA (slow-blow).

## 2.6 CONTROLS AND CONNECTORS

### Front panel

(1) AC SUPPLY switch. Press up to switch on. Pilot lamp indicates presence of rectified supply.

(2) LOCK switch. Press up to operate generator in locked mode. With the switch down, the generator can be operated independently of the synchronizer.

(3) OUT OF LOCK lamp. Goes out when generator is correctly locked.

(4) SYNC OUTPUT meter. Indicates control signal level of synchronizer, i.e. the position of the generator frequency within the lock range.

(5) Frequency switches. Seven rotary decade switches to select the desired frequency. Minimum increment is 100 Hz.

### Rear panel

(1) AC input connector. Mates with the connector fitted to the a.c. supply cable provided.

(2) Voltage selector switch. Selects either 95 to 132 V or 190 to 264 V to suit local a.c. supply.

(3) Fuse. AC input fuse rated at 160 mA (slow-blow) for 190 to 264 V or 250 mA (slow-blow) for 90 to 132 V.

(4) RF INPUT connector (TNC 50 Ω). Accepts the COUNTER OUTPUT signal from TF 2015.

(5) SYNC OUT connector BNC 50 Ω). Provides the synchronizer control signal to SYNC/SWEEP IN on TF 2015.

(6) 1 MHz STANDARD connector (BNC 50 Ω). Provides or accepts a 1 MHz standard frequency signal depending on the setting of the associated switch - see (7).

(7) 1 MHz STANDARD switch. When positioned at INT OUTPUT a 1 MHz signal derived from the 5 MHz crystal controlled oscillator is available at the connector. When positioned at EXT INPUT an external 1 MHz standard can be applied to the connector to replace the internal crystal standard.

## 2.7 SETTING FREQUENCY

The setting up procedure is as follows :

(1) With both synchronizer and generator connected to the a.c. supply and switched on, check that both pilot lamps are lit.

(2) On the synchronizer, set the frequency switches as required and switch to LOCK ON.

(3) On the generator, set the function selector at CW and the CARRIER switch at ON. Select the appropriate carrier range and check that the pointer of the MOD & CARRIER LEVEL meter is within the white box on the meter scale.

(4) Using the TUNE control, and FINE TUNE control if necessary, carefully adjust the generator frequency to extinguish the LOCK lamp on the synchronizer. Check that the pointer of the SYNC OUTPUT meter is stationary. It is advisable, particularly if the incremental frequency facility is to be used, to adjust the FINE controls to bring the pointer of the SYNC OUTPUT meter to the centre of the white box.

The signal generator frequency is now locked to the frequency shown on the synchronizer.

## 2.8 INCREMENTAL FREQUENCY ADJUSTMENT

Accurate incremental frequency changes up to 0.5% from the initial frequency setting can be obtained by readjusting only the synchronizer decade switches. This feature is useful for quickly and accurately checking narrow bandwidths, response of highly selective tuned circuits, or the response of s.s.b. receivers.

Incremental changes using the synchronizer will cause the deflection of the SYNC OUTPUT meter pointer to change, but the signal generator will be locked to the changed frequency provided the LOCK lamp remains unlit.

## 2.9 INDEPENDENT USE OF SIGNAL GENERATOR

Signal Generator TF 2015 can be used as an independent instrument without disconnecting the synchronizer. To use the generator in this way press the LOCK switch down. The SUPPLY switch should be left at ON to maintain the operational levels of the synchronizer in a 'stand-by' condition.

## 2.10 1 MHz OUTPUT

When the 1 MHz STANDARD switch is set at INT OUTPUT a 1 MHz signal derived from the 5 MHz crystal oscillator is available from the 1 MHz STANDARD connector. This feature enables the synchronizer to provide a 1 MHz standard frequency for driving external equipment such as a frequency counter.

## 2.11 USING AN EXTERNAL 1 MHz SOURCE

With the 1 MHz STANDARD switch at EXT INPUT a 2 V to 5 V square wave output from an external 1 MHz source can be applied to the 1 MHz STANDARD connector as a substitute for the internal 5 MHz standard of the synchronizer. This feature enables a common 1 MHz standard to be used as the fundamental source for the synchronizer and any auxiliary equipment.

If the instrument is inadvertently switched to accept an external standard when no external standard is connected, an incorrect synchronized condition will be obtained since the signal generator will then lock to the secondary standard in TF 2171.

With this condition, errors up to 300 kHz from the setting shown on the digital switches can occur. It is therefore essential to ensure that the INTERNAL OUT/EXTERNAL IN switch at the rear of the instrument is in the correct position. When an external standard is used it is recommended to check that the standard signal is present at the input socket at the rear of TF 2171.

Chapter 3

# Technical description

## 3.1 INTRODUCTION

This chapter, which should be read with reference to the drawings, illustrations and circuit diagrams contained within this manual, outlines the function of the synchronizer when used with Signal Generator TF 2015 and describes the operation of the circuits employed.

## 3.2 MECHANICAL CHARACTERISTICS

The synchronizer is constructed to be easily fitted to Signal Generator TF 2015 and to provide easy access to all components for adjustment or repair.

All printed circuit boards and sub-assemblies in the instrument are allocated a unit identification number in the sequence A0 to A4 and where practical the assembly is marked with this number; silk screening is used to identify the components on the printed circuit boards.

Instrument construction consists of front and rear panels supported by side plates which are designed to support an r.f. box and to carry the mains transformer (T1) and two i.c. packages (IC1 and IC3). The rear panel is used as a heat-sink for power transistor A0TR1 and the i.c. package IC2.

The r.f. box contains units A1, A2 and the frequency switches SA to SG. Unit A1 consists of the input amplifier and diode shaper circuits, the prescaler and the variable ratio dividers. Unit A2 carries the 5 MHz and 10 MHz oscillator circuits and associated dividers, the ramp generators, the phase detectors, the sample and hold driver circuits and the lock indicator circuit. The rear of the r.f. box carries the RF INPUT connector, the 1 MHz STANDARD connector together with its associated switch. The underside of the r.f. box is used to mount the r.f. filter assembly, the interface circuit Unit A3, the power supply rectifier/regulator circuits Unit A4 and the associated capacitors C23, C24 and C26.

The instrument case, which is in two sections and easily removed by extracting six screws, is fitted with a carrying handle and a fold-away tilt bar. Clips are attached to the case and a mounting kit is supplied to enable the synchronizer to be quickly fitted to Signal Generator TF 2015. A clip-on cover is provided to protect the front panel controls.

## 3.3 BASIC PRINCIPLE

When a synchronizer is used with a signal generator as shown in the block diagram Fig. 3.1 the configuration can be considered as a phase locked frequency synthesizer.

Output from the crystal oscillator at a frequency fr is passed to a series of fixed dividers to produce a reference frequency fr/m which is applied to one input of a phase detector. Output from the signal generator at a frequency fo is passed to a series of variable ratio dividers to produce a signal frequency fo/n which is applied to a second input of the phase detector. When the frequency of the generator is set such that

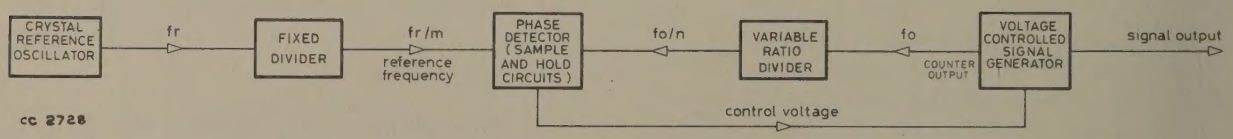



*Fig. 3.1 Simplified functional diagram*

fo/n is correctly related to fr/m the level of the control signal from the phase detector will be held constant. If the frequency of the generator drifts, the two frequencies will not be correctly related causing the control signal to vary in a manner such that the frequency of the generator is corrected.

The v.r.d. ratio (n) determines both the resolution (i.e. the smallest frequency increment that can be set) and the correction rate (i.e. the ability to deal with any rapid shifts in generator frequency). These two characteristics are conflicting since a high value of n is required for good resolution and a low value for high correction rate. In practice, this is overcome by including two phase locked loops: (i) a fast acting loop which provides large frequency increments and a high correction rate and (ii) a slow acting loop to provide the small increments.

## 3.4 CIRCUIT SUMMARY

The block diagram, Fig. 3.2, shows the functional arrangement of the synchronizer.

The input amplifier and the diode shaper provide a signal of the required form and amplitude to the prescaler which is included to ensure that the maximum operating frequency (40 MHz) of the variable ratio dividers is not exceeded.

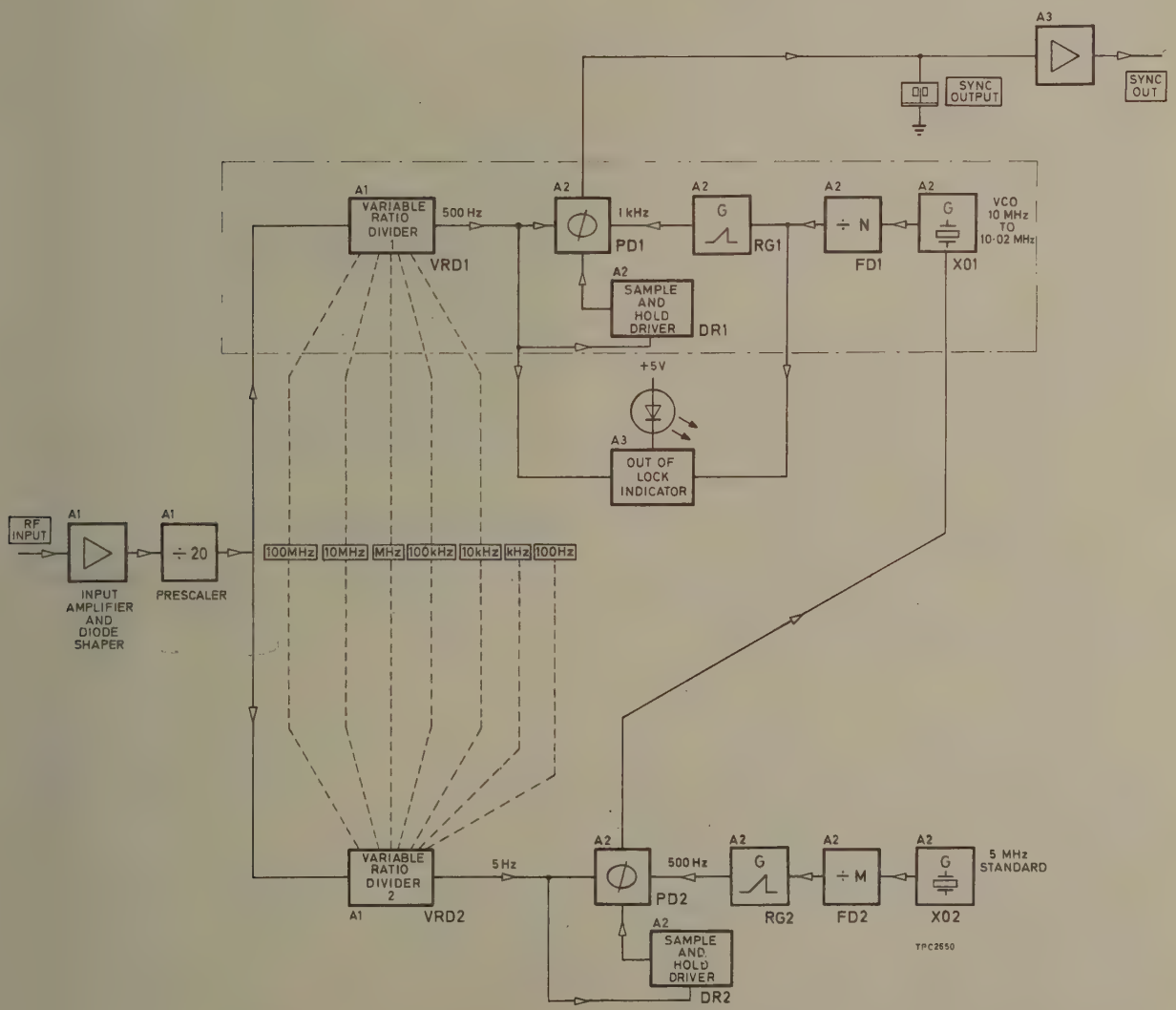



*Fig. 3.2 Simplified block diagram*

Output from the prescaler is passed to two variable ratio dividers VRD1 and VRD2.

### Fast acting loop

VRD1, which forms part of the first phase locked loop consists of only five divider stages to provide the control necessary for fast correction of any frequency change occurring in the generator and to allow incremental settings to 10 kHz. When the signal generator frequency is locked to that set on the synchronizer, VRD1 produces a series of output pulses at a p.r.f. of 500 Hz. The 500 Hz pulses are applied to a phase detector PD1 where they sample a train of ramp waveforms produced by a voltage tuned crystal oscillator, X01, and a series of decade dividers, FD1, to provide a control signal to the generator.

If the frequency of the generator is suddenly changed the output p.r.f. from VRD1 will shift above or below 500 Hz. This causes a change in the sampling rate and consequently a change in the level of the control signal to the generator - see Fig. 3.3a - which rapidly corrects its frequency before the second (slow) loop has time to operate.

### Slow acting loop

VRD2, which forms part of the second phase locked loop, consists of seven divider stages. When the 1 kHz and 100 Hz switches are each set at 0, VRD2 produces a series of output pulses at a p.r.f. of 5 Hz. The 5 Hz pulses are applied to a second phase detector PD2 where they sample a series of ramp waveforms produced by a 5 MHz crystal controlled oscillator X02 and a series of decade dividers FD2. The output of PD2 provides a control signal to the voltage tuned crystal oscillator X01 to set its frequency at 10 MHz.

To obtain increments of 1 kHz and 100 Hz the appropriate switches are moved to a number other than 0. This causes the output p.r.f. from VRD 2 to shift from 5 Hz so sampling occurs at a different position on the 500 Hz ramp, to consequently change the level of the control signal to the oscillator X01, as shown in Fig. 3.3b. The resulting slight change in the frequency of X01 increases the frequency of the ramp waveforms to PD1 such that the 500 Hz sampling pulses from VRD1 occur at a different position on the ramp. This causes the level of the control signal to the generator to change to provide the desired frequency increments.

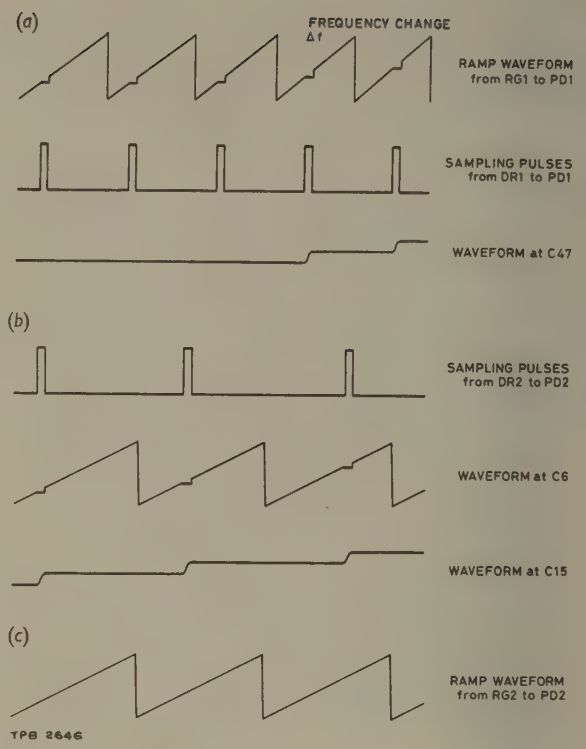



*Fig. 3.3 Sampling and ramp waveforms*

## 3.5 INPUT CIRCUIT

*Circuit diagram Fig. 7.1*

The amplifier consists of three common emitter stages TR1, TR2 and TR3 with the bias and gain of each stage set by the resistance/capacitance network connected between the collector and base of each transistor. To prevent a large signal causing overload and subsequent frequency doubling, the input to each stage incorporates a clamp diode D1, D2 and D3.

Output from the amplifier is applied to a clamping circuit D4 and D5. To ensure that the required signal level is passed to the prescaler the bias level to the diodes is preset by adjustment of R19.

Frequency division by a factor of twenty is obtained using a decade divider IC1 followed by a bistable IC2. Because the output of IC2 is at e.c.l. level it is passed to a common emitter amplifier TR4 to provide the voltage swing necessary to drive the t.t.l. circuits in the variable ratio dividers.

## 3.6 VARIABLE RATIO DIVIDERS

*Circuit diagram Fig. 7.2*

The two variable ratio dividers VRD1 and VRD2 differ only in the number of decade counters included in each, i.e. five and seven respectively. The two circuits which are interconnected as shown in Fig. 3.2 can be preset to any number from 0 to 9 to provide the desired overall division ratio.

When the digital switches are set at the required frequency, the counters will be preset to a number (X) equal to the complement of the desired division ratio (Y) with respect to the maximum content (Z) of the variable ratio divider, i.e. division ratio is Z-X. When input pulses are received from the prescaler the count will commence from X and continue to Z (counter full). The full condition is then detected and the signal is passed to the phase detector as a sampling pulse.

The overall function of the prescaler and the variable ratio dividers may be more clearly understood by reference to Fig. 3.4.

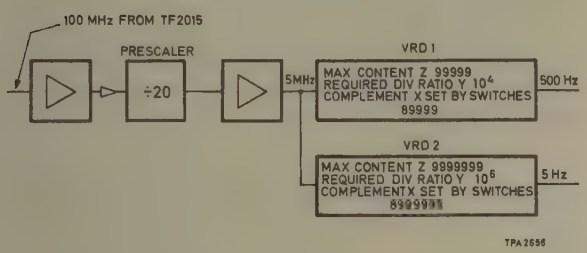



*Fig. 3.4 Functional diagram of variable ratio dividers*

Consider the operation of VRD2 (seven decade counters). The NAND gates IC6, IC5c3, IC7 and IC5a3 recognize when counters IC9 to IC14 are full, i.e. in the '9' state, and raise one input of the bistable IC3 to the high state. The remaining two inputs detect the '5' state of IC8 and allow IC3 and IC4 to count the following four clock pulses and provide a reset pulse to the counting chain as shown in Fig. 3.5.

The counting chain in VRD1 functions in exactly the same way.

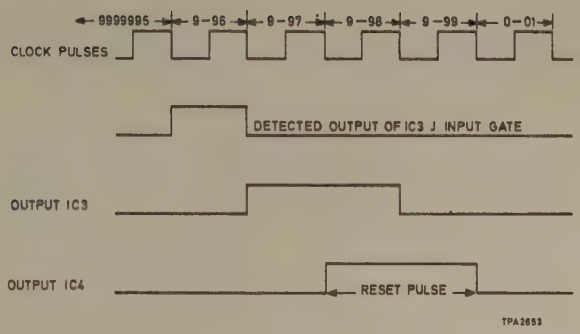



*Fig. 3.5 Waveforms of reset system*

## 3.7 STANDARD REFERENCE OSCILLATOR XO2

*Circuit diagram Fig. 7.3*

The fundamental reference frequency is provided by a 5 MHz temperature controlled crystal oscillator unit with an accuracy of 1 part in $10^7$. To enable its frequency to be precisely set at 5 MHz, the unit has two controls (a) a trimmer which provides an initial adjustment and (b) an external control R5 for final adjustment.

Output from the oscillator is a 5 V square wave which is suitable for driving the t.t.l. circuits in the standard divider FD2.

## 3.8 FIXED FREQUENCY DIVIDERS

*Circuit diagram Fig. 7.3*

Two fixed divider chains are used in the instrument and the function of each is as follows.

Divider FD2, which is driven by the 5 MHz crystal controlled oscillator, consists of four decade counters IC4, IC5, IC6 and IC7 connected in cascade to provide an output frequency of 500 Hz. The square wave output from IC7 is applied to IC8 to produce a train of narrow positive going pulses at a p.r.f. of 500 Hz to the ramp generator RG2. Since each integrated circuit (IC4 to IC7) consists of two sections arranged to divide by five and two, an accurate 1 MHz output is available when the output of the 5 MHz reference oscillator has passed through the divide by five section of IC4.

The other fixed divider FD1, which is driven by the 10 MHz voltage tuned crystal oscillator, consists of four decade dividers IC15, IC16, IC17 and IC18 connected in cascade to provide an output of 1 kHz. The square wave output from IC18 is applied to IC19 to produce a train of narrow positive going pulses at a p.r.f. of 1 kHz to the ramp generator RG1.

## 3.9 RAMP GENERATORS

*Circuit diagram Fig. 7.3*

The two ramp generators RG1 and RG2 each consist of a constant current source, a transistor switch and a capacitor; their operation, which is explained with reference to RG2, is in principle the same.

During the interval between the 500 Hz pulses, transistor TR1 is non-conducting causing capacitor C2 to be linearly charged to the required level by the constant current source provided by the circuit of TR2. The arrival of a pulse at the base of TR1 causes this transistor to conduct and rapidly discharge C2. The generated waveform is as shown in Fig. 3.3(c).

## 3.10 SAMPLE AND HOLD PHASE DETECTORS

*Circuit diagram Fig. 7.3*

Since the two sample and hold phase detectors PD1 and PD2 are basically the same their operation can be explained with reference to the circuit of PD2.

During the interval between the sampling pulses from VRD2 transistor TR5 is on to allow the output from the ramp generator to charge the sampling capacitor C6 while TR7 is off, to isolate the hold capacitor C15 from the ramp input.

When the sampling pulse from the v.r.d. appears TR5 is switched off to isolate C6 which now holds a voltage at a level which has been determined by the position of the sampling pulse on the ramp. Transistor TR7 is now switched on for a short period to transfer the voltage at C6 to the hold capacitor C15. Since the voltage at C15 determines the level of the control signal to the voltage tuned crystal oscillator X01 and consequently its set frequency, it is monitored by the f.e.t. follower circuit TR8 to ensure that it is not discharged during the interval between sampling pulses.

## 3.11 SAMPLE AND HOLD DRIVER CIRCUITS

*Circuit diagram Fig. 7.3*

Operation of the phase detectors PD1 and PD2 is controlled by the sample and hold driver circuits DR1 and DR2. Except for the value of the components, the two circuits are similar so their function can be explained with reference to the circuit of DR2 which uses the three monostables IC1, IC2 and IC3. For sampling it is necessary to switch TR5 off just before TR7 is switched on to ensure that only a pure d.c. voltage is transferred to C15. To achieve this the output pulses from VRD2 are applied to the monostable IC1 to produce positive going pulses of the required duration to switch TR4 on and consequently TR5 off during the transfer periods.

Monostable IC2 provides a small delay before IC3 supplies the required negative going pulses to switch TR6 off and consequently TR7 on - see Fig. 3.6.

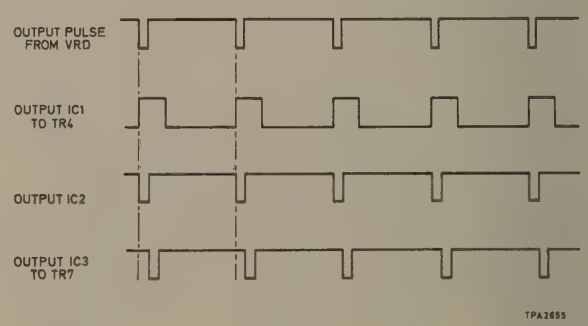



*Fig. 3.6 Waveforms of sample and hold circuits*

## 3.12 VOLTAGE TUNED CRYSTAL OSCILLATOR

*Circuit diagram Fig. 7.3*

Transistors TR9 and TR10 together with the crystal unit X01 and the circuit L1 D1 form an emitter coupled voltage tuned crystal oscillator which functions as follows:

The crystal, which operates as a series tuned circuit at 10.02 MHz, is connected in series with a second tuned circuit L1 and varactor D1 as shown in Fig. 3.7. The capacitive component Cx of the crystal is very small, being typically 0.01 pF, whilst its inductive component Lx is very large, i.e. several henries. Inductance L1 of the external circuit is very small compared with Lx whilst the capacitance of the varactor D1 is large compared with Cx. Since the capacitance of D1 is effectively in series with Cx its capacitive variations produce only small frequency changes within the tuned frequency range (10-10.02 MHz) of the oscillator. The capacitance of D1 and consequently the frequency of the circuit is determined by the d.c. output from PD1.

Output from the oscillator is passed to an amplifier TR11 to provide the signal level required to drive the t.t.l. circuits in the divider FD1.

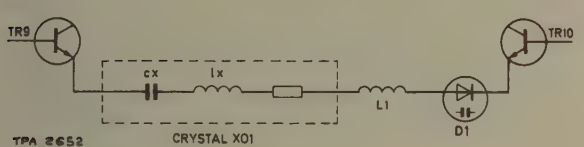



*Fig. 3.7 Functional diagram of voltage tuned crystal oscillator*

## 3.13 OUT-OF-LOCK INDICATOR CIRCUIT

*Circuit diagram Fig. 7.3*

Operation of the out-of-lock indicator circuits is best described with reference to the functional diagram Fig. 3.8 which identifies the circuits used and illustrates their performance when the signal generator is in the locked mode.

The 1 kHz pulses (b) from the fixed divider FD1 are applied to a bistable IC12 to provide a train of 500 Hz pulses (c) to the monostable IC14 which also receives the narrow 500 Hz pulses (a) from the variable ratio divider VRD1.

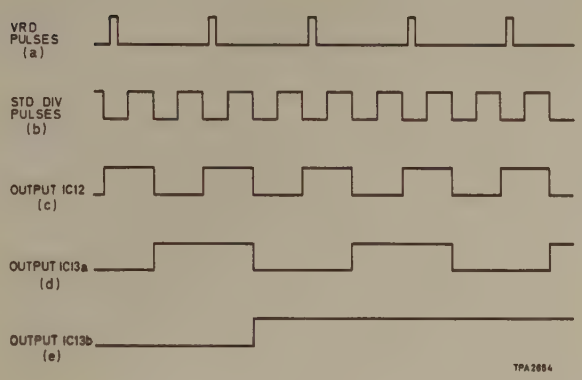



*Fig. 3.8 Waveforms of out-of-lock indicator circuit*

It is shown by relating waveforms (a) and (c) that when the signal generator is in the locked mode the v.r.d. pulses occur during the time that the output from IC12 is high. With this condition the two respective inputs to the monostable IC14 will be high, the monostable will not be triggered and the out-of-lock indicator will be unlit.

When the signal generator is not in lock the p.r.f. output from VRD1 is then not at 500 Hz so consequently the v.r.d. pulses do not always occur during the period when the output from IC12 is high. With this condition the respective inputs to the monostable will be received at different times and the monostable will be triggered causing the out-of-lock indicator to be lit.

To ensure that when the signal generator is in the locked mode the output pulses (b) from IC12 and the pulses (c) from the v.r.d. are maintained in phase a 'clear pulse' obtained from IC11 in the sample and hold driver circuit is applied to IC12 to immediately follow each v.r.d. pulse.

The circuit as described so far will not give an out-of-lock indication if the generator is at a sub-harmonic of that set on the synchronizer; therefore, to prevent false locking which could occur from this, a divide by four circuit IC13a and IC13b - see Fig. 3.9 - is included to produce waveforms (d) and (e). The inverted waveform

(e) from IC13b allows the monostable to trigger from the v.r.d. pulses despite the high level condition of waveform (c). It is also fed back to IC13a to prevent the circuits clocking so it is held in this state until the v.r.d. pulse is present and the following 'clear pulse' resets the circuits. The waveforms shown are those obtained in the absence of a 'clear pulse'.

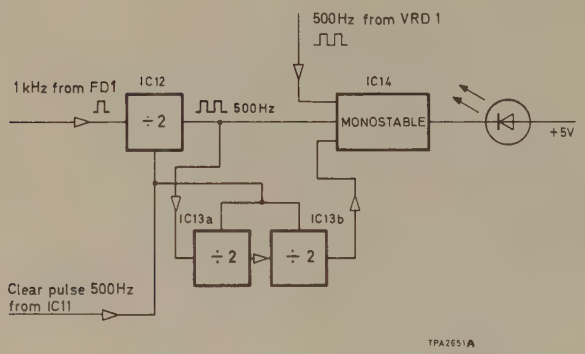



*Fig. 3.9 Block diagram of false lock prevention circuits*

## 3.14 INTERFACE AMPLIFIER

*Circuit diagram Fig. 7.1*

The interface amplifier circuit serves to convert the control voltage from the phase detector PD1 to a current drive for TF 2015. For voltage/current conversion transistors TR3 and TR6 form a long-tail pair with TR5 operating as a current inverter to add the current flowing through TR6 to that flowing through TR3. The circuit, which includes the temperature compensating diodes D3 and D4, has been balanced by selecting values for R13 and R17 such that no current flowed in a split load connected across the supply rails with the input connected to earth.

Because the tuning varactors in the TF 2015 oscillators have a non-linear voltage/capacitance characteristic the sensitivity of the synchronizer input on TF 2015 varies as the generator is tuned over each range. To maintain the loop gain within the desired limits the input signal to the interface is controlled by the circuit TR1, TR2 and the voltage/resistance converter APC1 consisting of the light emitting diode D2 and the light sensitive resistor PCC1, which functions as follows.

When the loop gain is high a large current flows through D2 causing it to be lit; this consequently lowers the resistance of PCC1 to accordingly reduce the signal level to the interface amplifier. With a lower loop gain the current flowing through D2 is not sufficient to cause it to be lit. The resistance of PCC1 is then increased such that the attenuator formed by R6 and PCC1 has little effect on the signal level to the interface amplifier.

## 3.15 POWER UNIT

*Circuit diagram Fig. 7.4*

The power unit, which operates from switch selected a.c. supplies of 95 to 130 V or 190 to 264 V, 45 to 500 Hz, consists of a mains transformer T1 with three secondary windings, three full wave rectifier circuits and four regulators to produce stabilized supplies of +24 V, +12 V, +5 V and -12 V. Connection to the a.c. supply is made through a three pin connector, a supply switch SH and a fuse FS1. The on/off indicator is a light emitting diode D2 which is operated from the +12 V supply.

The three voltage regulators IC1, IC2 and IC3, which provide stabilized supplies of +12 V, +5 V and +24 V respectively, also include protection against overload and external short circuit. The -12 V supply uses an operational amplifier IC4 with transistor TR1 as the regulating element. The reference is the 0V line and the sampling point is the junction of resistors R5 and R6 connected between the +12 V and -12 V rails.

The supply filters, which are contained in a screened box, are connected in series with various supply lines to minimize the introduction of any spurious r.f. Each consists of two screened sections using either a 6 or 10 μH inductor and lead-through capacitors.

Chapter 4

# Maintenance

## 4.1 INTRODUCTION

This chapter contains information to enable the performance of the synchronizer to be maintained. It should be read with reference to Chapter 3 and the illustrations and circuit diagrams contained within this manual.

**CAUTION**

The instrument uses semiconductor devices which, although having inherent long term reliability, can be damaged by overloads, reverse polarity and excessive heat or radiation. Care should be exercised to ensure that d.c. supplies are not reversed and to avoid prolonged soldering and strong r.f. fields. Before applying continuity or insulation tests or before shorting or breaking a circuit refer to the circuit diagram to establish the effect on the bias arrangement of the devices employed.

NOTE (1). Test waveforms may vary slightly from the typical waveforms illustrated in Fig. 4.3 (a to y).

(2). The checks given in this section are simplified and of restricted range compared with those which would be needed to demonstrate complete compliance with the specification. They should be regarded only as providing a procedure, for routine maintenance, to determine whether adjustment or repair is necessary.

(3). Voltages given on the circuit diagrams approximate those which can be expected using a 20 kΩ/V meter on a typical TF 2171 connected to an a.c. supply of 240 V, 50 Hz. All voltage levels are with respect to chassis.

## 4.2 SCREW FASTENERS

The majority of screw threads are metric of various sizes but in some positions BA threads are used. All chromium plated screws and all screws tinted blue are metric.

Ensure that screws removed are refitted in original positions.

## 4.3 ACCESS TO SUB-ASSEMBLIES AND COMPONENTS

### Removal of case

The case is in two sections. Remove the six screws (three each side) at the rear of the instrument then slide off the top and bottom sections.

### Unit A1

To obtain access to Unit A1 shown in Fig. 4.1, remove the lid of the r.f. box. Unit A1 is hinged to provide access to Unit A2 and the frequency switches. It also enables direct connection to components for purpose of test and simplifies the replacement of a faulty component.

### Unit A2

Direct access to Unit A2 is obtained by first removing the three holding screws at the rear of Unit A1 and then by folding Unit A1 back on its hinge. Unit A2 is also hinged as shown in Fig. 4.1 to provide access to inputs of the filter box and components. Prior to folding A2 back it is necessary that the push on connections to tags 11, 12, 13 with sleeves brown, red and orange respectively, be temporarily removed.

### Units A3 and A4

These units are located on the underside of the instrument and are directly accessible as shown in Fig. 4.2.

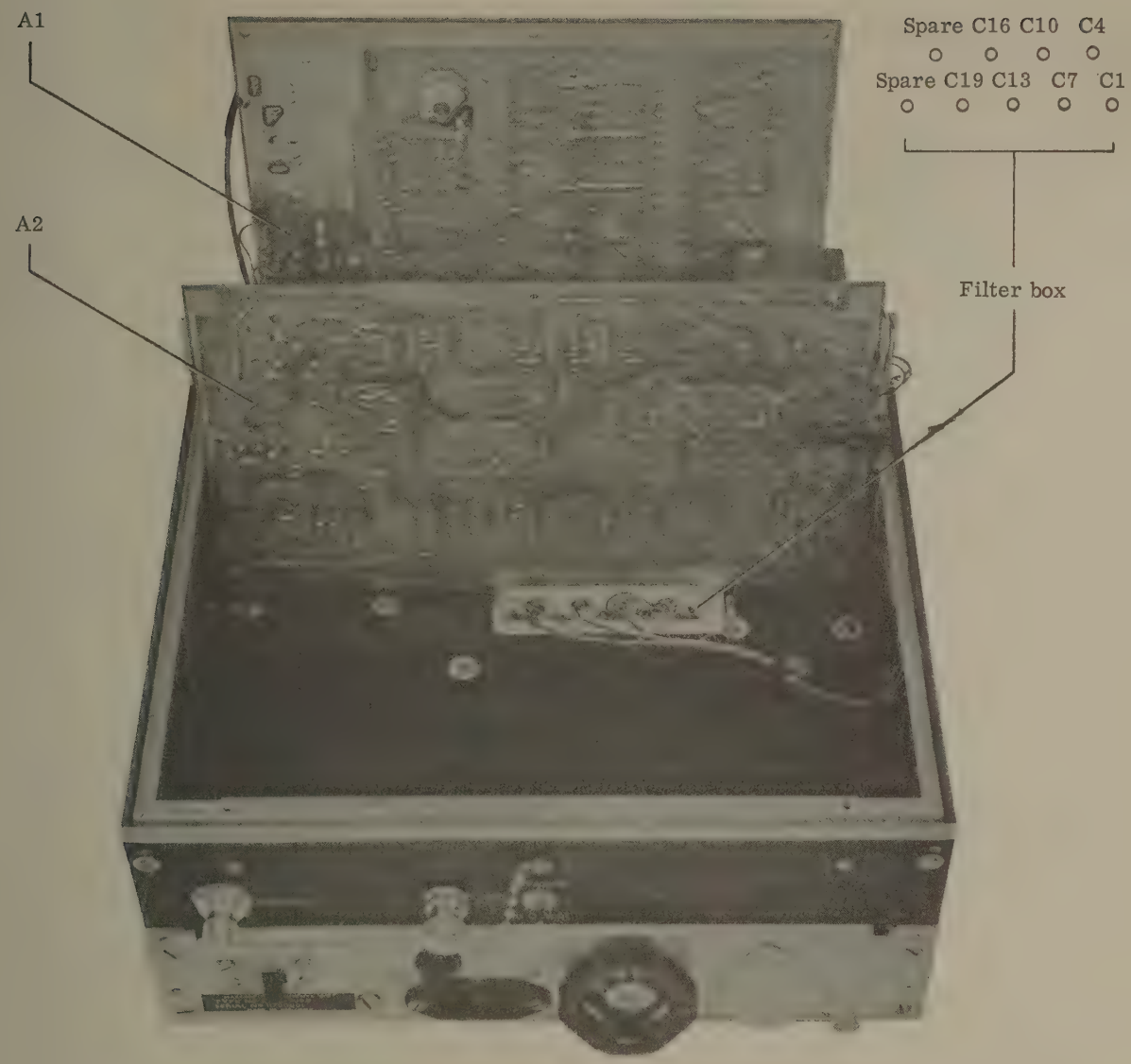



*Fig. 4.1 Top view with units hinged back*

### Subsidiary assemblies

The location of subsidiary assemblies and various components is also shown in Figs. 4.1 and 4.2.

## 4.4 PRELIMINARY CHECKS

(1) Check to ensure that all switches are undamaged and operating correctly and verify that connectors are securely mated.

(2) Check that fuse is of the correct rating and type and fits correctly in the holder.

(3) Check that the voltage selector switch is set to suit the local supply.

## 4.5 TEST EQUIPMENT

The test equipment required for maintenance and repair of the instrument is listed in Table 4.1.

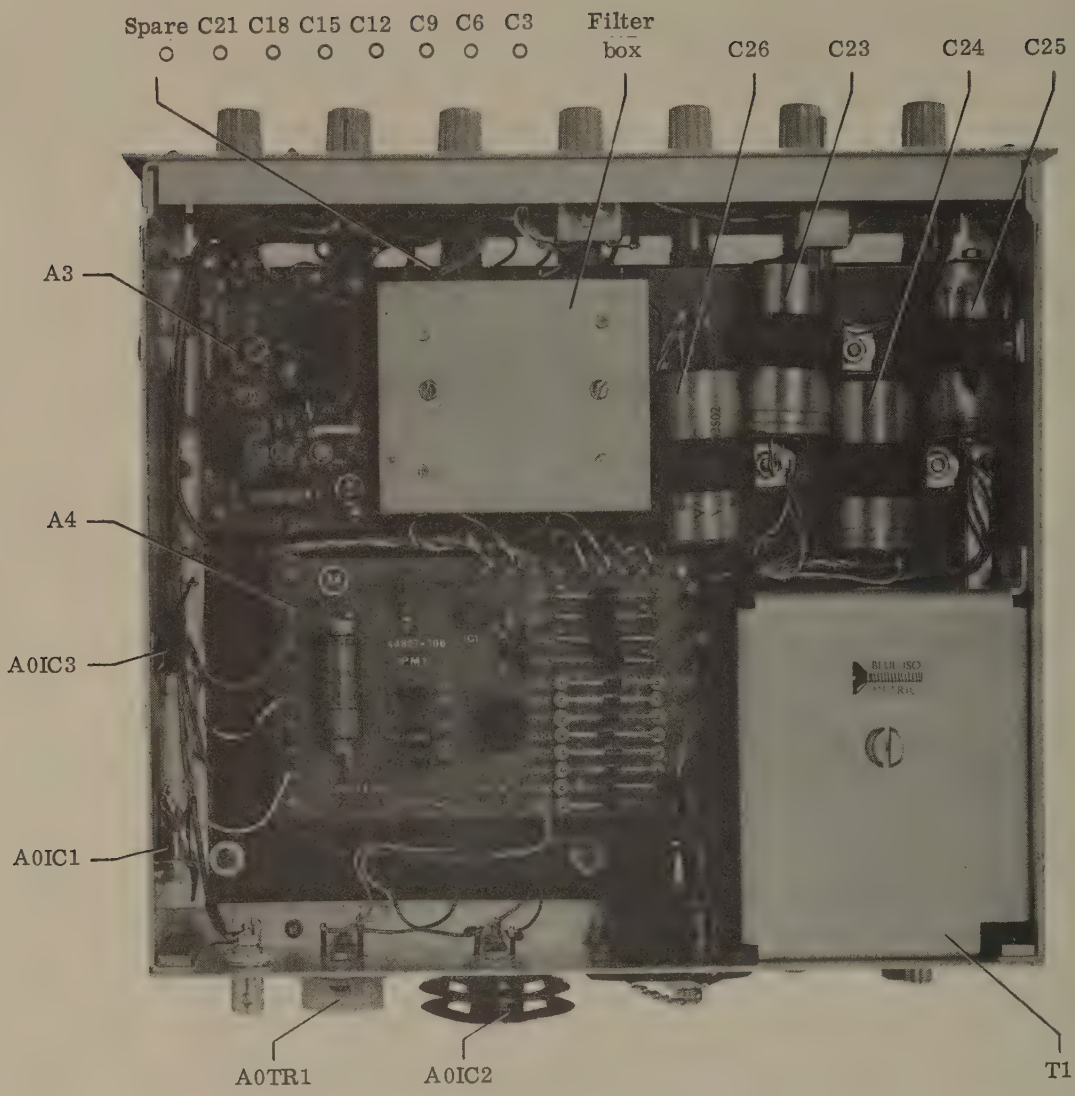



*Fig. 4.2 Underside view*

**Table 4.1**

| *Item* | *Description* | *Recommended model* |
|---|---|---|
| a | Multimeter | GEC Selectest or Avometer Model 8 |
| b | Oscilloscope | Minimum requirements :<br>(a) Dual trace<br>(b) Time base : 10 ns to 100 ms<br>(c) Rise time : 2 ns<br>(d) Amplitude measurement : 0 to 25 V |
| c | Input probe ($\div$ 10) | Suitable for above |
| d | Frequency counter | Marconi TF 2410 (standardized to 1 part in $10^8$ at 5 MHz) |
| e | Variable voltage transformer | Variac or equivalent |

## 4.6 OVERALL PERFORMANCE CHECK

Test equipment : item d.

With TF 2015 and TF 2171 connected together and switched on, correct performance can be quickly proved by the following test :

(1) Connect the frequency counter to the RF OUTPUT on TF 2015.

(2) Set TF 2171 at 100 MHz (1000000) and the LOCK switch at ON.

(3) Set TF 2015 at 100 MHz and carefully tune to extinguish the OUT OF LOCK lamp. Then check that the counter indicates 100 MHz.

(4) Set only TF 2171 at 100 MHz + 10 kHz (1000100) then check that the counter now indicates 100.01 MHz and that the OUT OF LOCK lamp remains unlit.

## 4.7 CIRCUIT CHECKS AND ADJUSTMENTS

The following functional checks should be performed to prove correct operation of the various circuits or to localize the cause of incorrect instrument performance. Where possible, adjustments are described for obtaining the required result.

### 4.7.1 Power supplies (A4)

Test equipment : items a, e.

(1) With TF 2171 disconnected from the a.c. supply remove connections to pins 14, 15, 17 and 18.

(2) With TF 2171 connected to the a.c. supply and switched on, connect the multimeter between pin 18 (positive) and pin 8 (negative) and check that the meter indicates 5.25 V. If necessary adjust R3 to obtain this voltage.

(3) Connect the multimeter in turn between pin 14 (positive) and pin 8 (negative) and pin 17 (positive) and pin 8 (negative) and check that the indicated voltages are 24 V ±1 V and 12 V ±0.5 V respectively.

(4) Connect the multimeter between pin 8 (positive) and pin 15 (negative) and check that the indicated voltage is 12 V ±0.5 V.

(5) Reconnect pins 14, 15, 17 and 18 and check that all voltage levels have remained the same.

(6) Connect the a.c. supply through the variable voltage transformer and check that with inputs to the power supply of between 190 and 260 V (or 95 and 130 V) the voltages as measured in (2), (3) and (4) remain within ±100 mV.

### 4.7.2 Input amplifier (A1)

Test equipment : items b, c.

(1) With TF 2015 connected to TF 2171 and switched ON set the generator frequency at 20 MHz and the RF OUTPUT controls fully clockwise, i.e. 0 and -7 dBm.

(2) Using the probe connect the oscilloscope to the junction of D4 and D5 and check that the waveform is as shown in Fig. 4.3 (a). If necessary adjust R19 to obtain the required amplitude.

(3) Set the r.f. output of TF 2015 at -13 dBm and check that the waveform shown is approximately the same, i.e. as Fig. 4.3 (a).

### 4.7.3 Prescaler unit (A1)

Test equipment : items b, c.

(1) With the frequency of TF 2015 at 20 MHz and the RF OUTPUT controls fully clockwise, connect the oscilloscope to the collector of TR4 and check that the waveform is as Fig. 4.3 (b).

(2) Set the frequency of TF 2015 at 500 MHz and the RF OUTPUT controls at -13 dBm and check that the waveform is as Fig. 4.3 (c).

### 4.7.4 Variable ratio dividers (A1)

Test equipment : items b, c.

(1) With the frequency of TF 2015 at 20 MHz and the RF OUTPUT controls fully clockwise set TF 2171 at 0000020.

(2) Connect the oscilloscope to pin 31 and check that the waveform is as Fig. 4.3 (d).

(3) Set TF 2171 at 0002000 then connect the oscilloscope to pin 32 and check that the waveform is the same i.e. as Fig. 4.3 (d).

### 4.7.5 5 MHz oscillator and divider FD2 (A2)

Test equipment : items b, c, d.

(1) Allow ten minutes from 'switch on' for the temperature of the crystal oven to stabilize then, using the oscilloscope probe, connect the counter to pin 1 on IC4 and check that the indicated frequency is 5 MHz ±0.5 Hz. If necessary carefully adjust R5 to obtain this requirement.

(2) Remove the counter. Then, using the probe, connect the oscilloscope to pin 1 on IC4 and check that the waveform is as Fig. 4.3 (e).

(3) Connect the oscilloscope to pin 8 on IC8 and check that the waveform is as Fig. 4.3 (f).

### 4.7.6 Ramp generator RG2 (A2)

Test equipment : items b, c.

(1) Set TF 2015 and TF 2171 at 20 MHz and the RF OUTPUT controls on TF 2015 fully clockwise.

(2) Connect the oscilloscope to the collector of TR1 and check that the waveform is as Fig. 4.3 (g). If necessary adjust R3 to obtain the required ramp amplitude.

(3) Connect the oscilloscope to the emitter of TR3 and check that the waveform is as Fig. 4.3 (h).

### 4.7.7 Sample and hold driver circuit DR2 (A2)

Test equipment : items b, c.

(1) With TF 2015 and TF 2171 as in 4.7.6 (1) connect the oscilloscope in turn to the points listed below :

(a) pin 6 on IC1 for waveform Fig. 4.3 (i)
(b) pin 6 on IC2 for waveform Fig. 4.3 (j)
(c) pin 6 on IC3 for waveform Fig. 4.3 (k)
(d) collector of TR4 for waveform Fig. 4.3 (l)
(e) collector of TR6 for waveform Fig. 4.3 (m)

### 4.7.8 Voltage tuned crystal oscillator and divider FD1 (A2)

Test equipment : items b, c.

(1) With TF 2015 locked to TF 2171 at 10 MHz connect the oscilloscope to the source of TR7 and check by carefully triggering the oscilloscope that the waveform is as Fig. 4.3 (y). If necessary slightly adjust the core of L1 to position the step on the ramp at the required amplitude.

(2) Connect the oscilloscope in turn to the collectors of TR10 and TR11 and check that the waveforms are as Fig. 4.3 (n) and 4.3 (o) respectively.

(3) Connect the oscilloscope to pin 8 on IC19 and check that the waveform is as Fig. 4.3 (p).

### 4.7.9 Ramp generator RG1 (A2)

Test equipment : items b, c.

With TF 2015 and TF 2171 set at 20 MHz and with the TF 2015 RF OUTPUT controls fully clockwise, connect the oscilloscope to collector of TR12 and check that the waveform is as Fig. 4.3 (q).

### 4.7.10 Sample and hold driver circuit DR1 (A2)

Test equipment : items b, c.

(1) With TF 2015 and TF 2171 as in 4.7.9, connect the oscilloscope in turn to pin 6 on IC9,

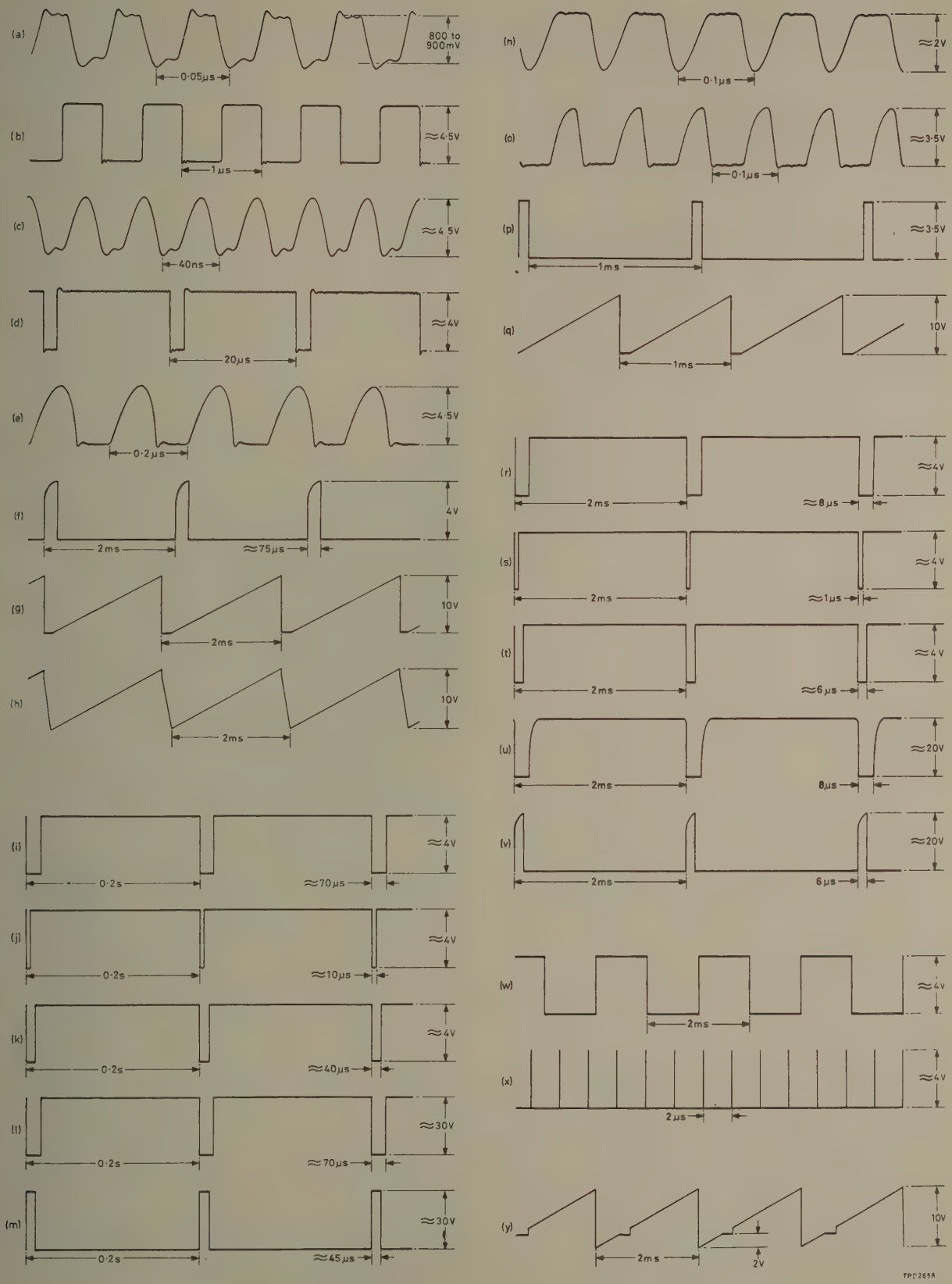



*Fig. 4.3 Typical waveforms*

pin 6 on IC10 and pin 6 on IC11 and check that the waveforms are as Figs. 4.3 (r), 4.3 (s) and 4.3 (t) respectively.

(2) Connect the oscilloscope in turn to collector of TR15 and TR17 and check that the waveforms are as Figs. 4.3 (u) and 4.3 (v).

### 4.7.11 Lock indicator circuits (A3)

Test equipment : items b, c.

(1) With TF 2015 locked to TF 2171 at any frequency connect the oscilloscope to pin 2 on IC12 and check that the waveform is as Fig. 4.3 (w).

(2) Connect the oscilloscope in turn to pin 6 on IC13, pin 3 on IC14 and pin 6 on IC14 and check that the waveform at each point is as Fig. 4.3 (x).

(3) Connect the oscilloscope to pin 2 on IC14 and check that this point is at low logic level.

### 4.7.12 Interface amplifier (A3)

Test equipment : item a.

(1) Disconnect the interconnecting cables between TF 2171 and TF 2015.

(2) Disconnect the coaxial cable from pin 9 and connect pin 9 to pin 8.

(3) Connect two 47 kΩ ±1% resistors in series between pins 1 and 5.

(4) Set the LOCK switch UP (lock) then with the multimeter set at 50 μA f.s.d. and connected between pin 2 and the junction of the 47 kΩ resistors, check that the multimeter indicates zero current. If necessary, change the value of either R13 or R17 to obtain a zero current result.

(5) Remove the resistors and the connection between pins 8 and 9 and reconnect the coaxial cable.

## 4.8 CLEANING ROTARY SWITCHES

These should be cleaned two or three times a year depending upon use. Only benzene or white spirit (not carbon tetrachloride) should be used. After cleaning, carefully wipe the contacts with a lubricant of 1% solution petroleum jelly in white spirit.

## 4.9 ADDITIONAL INFORMATION

If further information is required please write to or telephone Marconi Instruments Limited, Service Division - see address on back cover - or contact our nearest representative, quoting the type and serial number on the data plate on rear of the instrument.

If the instrument is being returned for repair please indicate clearly the nature of the fault or the work you require to be done.

Chapter 6

# Replaceable parts

## Introduction

Each sub-assembly or printed circuit board in this instrument has been allocated a unit identification in the sequence A0 to A4.

The complete component reference carries its unit number as a prefix e.g. A1C1 but for convenience in the text and on circuit diagrams the prefix is not used.

However, when ordering replacements or in correspondence the complete component reference must be quoted.

One or more of the components fitted in this instrument may differ from those listed in this chapter for any of the following reasons :

(a) Components indicated by a † have their value selected during test to achieve particular performance limits.

(b) Owing to supply difficulties, components of different value or type may be substituted provided the overall performance of the instrument is maintained.

(c) As part of a policy of continuous development, components may be changed in value or type to obtain detail improvements in performance.

When there is a difference between the component fitted and the one listed, always use as a replacement the same type and value as found in the instrument.

## Ordering

When ordering replacements, address the order to our Service Division (address on rear cover) or nearest agent and specify the following for each component required.

(1) Type and serial number of instrument

(2) Complete circuit reference

(3) Description

(4) M.I. code number

## Component references

The components are listed in alphanumerical order and the following abbreviations are used:

| | | |
|---|---|---|
| C | : | capacitor |
| Carb | : | carbon |
| Cer | : | ceramic |
| Cerm | : | cermet |
| D | : | semiconductor diode |
| Elec | : | electrolytic |
| FS | : | fuse |
| IC | : | integrated circuit (package) |
| L | : | inductor |
| Max | : | maximum |
| ME | : | meter |
| Met | : | metal |
| Mic | : | mica |
| Min | : | minimum value |
| Ox | : | oxide |
| PL | : | plug |
| Plas | : | plastic dielectric |
| R | : | resistor |
| S | : | switch |
| SK | : | socket |
| T | : | transformer |
| Tant | : | tantalum |
| TP | : | terminal |
| TR | : | transistor |
| Var | : | variable |
| WW | : | wirewound |
| XO | : | crystal oscillator |
| † | : | value selected during test; nominal value listed |
| Ø | : | feed-through component |
| W | : | watts at 70°C |

| Circuit reference | Description | M.I. code |
|---|---|---|
| **Unit A0** | | |
| *When ordering, prefix circuit reference with A0* | | |
| C1 to C21 | Cer Ø 0.001µF -20+80% 500V | 26373-733 |
| C22 | Elec 470µF -20+80% 25V | 26415-822 |
| C23 | Elec 2200µF -10+100% 40V | 26426-086 |
| C24 | Elec 2200µF -10+100% 40V | 26426-086 |
| C25 | Elec 4700µF -10+50% 16V | 26426-091 |
| C26 | Elec 1000µF -20+100% 63V | 26426-081 |
| C27 | Tant 0.47µF 20% 35V | 26486-207 |
| C28 | Tant 0.47µF 20% 35V | 26486-207 |
| C29 | Plas 0.47µF 10% 100V | 26582-215 |
| C30 | Tant 0.47µF 20% 35V | 26486-207 |
| C31 | Tant 0.47µF 20% 35V | 26486-207 |
| C32 | Tant 0.47µF 20% 35V | 26486-207 |
| D1 | LED (on/off indicator) | 28624-104 |
| D2 | LED ( out of lock indicator) | 28624-104 |
| FS1 | 160 mA (slow blow) 190-264V | 23411-054 |
| | or 250 mA (slow blow)95-130V | 23411-055 |
| IC1 | Regulator 12V | 28461-708 |
| IC2 | Regulator 5V | 28461-704 |
| IC3 | Regulator 24V | 28461-710 |
| L1 | Filter coil 10µH | 23642-555 |
| L2 | Filter coil 10µH | 23642-555 |
| L3 | Filter coil 6µH | 44290-023 |
| L4 | Filter coil 6µH | 44290-023 |
| L5 | Filter coil 10µH | 23642-555 |
| L6 | Filter coil 10µH | 23642-555 |
| L7 | Filter coil 10µH | 23642-555 |
| L8 | Filter coil 10µH | 23642-555 |
| L9 | Filter coil 6µH | 44290-023 |
| L10 | Filter coil 6µH | 44290-023 |
| L11 | Filter coil 10µH | 23642-555 |
| L12 | Filter coil 10µH | 23642-555 |
| L13 | Filter coil 10µH | 23642-555 |
| L14 | Filter coil 10µH | 23642-555 |
| ME1 | Meter | 44559-003 |
| R1 | Met film 750Ω 2% ¼W | 24773-270 |
| R2 | Met film 200Ω 2% ¼W | 24773-256 |
| SA | Frequency switch Hz x 100 | 44340-052 |
| SB | Frequency switch kHz | 44340-052 |
| SC | Frequency switch kHz x 10 | 44340-052 |
| SD | Frequency switch kHz x 100 | 44340-052 |
| SE | Frequency switch MHz | 44340-052 |
| SF | Frequency switch MHz x 10 | 44340-052 |
| SG | Frequency switch MHz x 100 | 44340-052 |
| SH | Supply switch DPDT | 23462-258 |
| SJ | Voltage selector switch 230V/115V | 23467-155 |
| SK | Lock switch DPDT | 23462-258 |
| SL | 1 MHz - STD switch DPDT | 23462-258 |
| T1 | Mains transformer | 43490-015 |
| TR1 | Transistor MJ 491 | 28435-876 |

**Unit A1**

*When ordering, prefix circuit reference with A1*

| | | |
|---|---|---|
| | Complete board | 44827-303 |
| C1 | Cer 0.001µF -20+80% 500V | 26383-242 |
| C2 | Cer 10pF 20% 500V | 26343-120 |
| C3 | Cer 0.001µF -20+80% 500V | 26383-242 |
| C4 | Cer 0.01µF -20+80% 100V | 26383-055 |
| C5 | Cer 0.001µF -20+80% 500V | 26383-242 |

*For symbols and abbreviations see introduction to this chapter*

| Circuit reference | Description | M.I. code |
|---|---|---|
| C6 | Cer 6.8pF ±0.5pF 500V | 26343-116 |
| C7 | Cer 0.001μF -20+80% | 26383-242 |
| C8 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C9 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C10 | Cer 8.2pF ±0.5pF 500V | 26343-118 |
| C11 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C12 | Elec 220μF -20+100% 10V | 26415-817 |
| C13 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C14 | Cer 6.8pF ±0.5pF 500V | 26343-116 |
| C15 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C16 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C17 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C18 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C19 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C20 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C21 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C22 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C23 | Cer 82pF 10% 500V | 26343-165 |
| C24 | Plas 0.22μF 10% 63V | 26582-406 |
| C25 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C26 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C27 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C28 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C29 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C30 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C31 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C32 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C33 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C34 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C35 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C36 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C37 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C38 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C39 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C40 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C41 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C42 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C43 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C44 | Cer 0.01μF -20+80% 100V | 26383-055 |
| D1 | Diode MBD 102 | 28349-004 |
| D2 | Diode MBD 102 | 28349-004 |
| D3 | Diode MBD 102 | 28349-004 |
| D4 | Diode MBD 102 | 28349-004 |
| D5 | Diode MBD 102 | 28349-004 |
| D6 | Diode Zener 156006A | 28371-549 |
| IC1 | High speed counter | 28464-007 |
| IC2 | JK bistable (120 MHz) | 28462-006 |
| IC3 | High speed JK bistable | 28462-014 |
| IC4 | High speed JK bistable | 28462-014 |
| IC5 | Hex inverter | 28469-159 |
| IC6 | 8-input NAND gate | 28466-330 |
| IC7 | 8-input NAND gate | 28466-330 |
| IC8 | High speed counter | 28464-004 |
| IC9 | High speed counter | 28464-004 |
| IC10 | High speed counter | 28464-004 |
| IC11 | High speed counter | 28464-004 |
| IC12 | High speed counter | 28464-004 |
| IC13 | High speed counter | 28464-004 |
| IC14 | High speed counter | 28464-004 |
| IC15 | High speed counter | 28464-004 |
| IC16 | High speed counter | 28464-004 |
| IC17 | High speed counter | 28464-004 |
| IC18 | High speed counter | 28464-004 |
| IC19 | High speed counter | 28464-004 |
| IC20 | High speed JK bistable | 28462-014 |
| IC21 | High speed JK bistable | 28462-014 |
| IC22 | 8-input NAND gate | 28466-330 |

*For symbols and abbreviations see introduction to this chapter*

| Circuit reference | Description | M.I. code |
|---|---|---|
| R1 | Met film 39Ω 2% ¼W | 24773-239 |
| R2 | Met film 24 kΩ 2% ¼W | 24773-306 |
| R3 | Met film 240Ω 2% ¼W | 24773-258 |
| R4 | Met film 680Ω 2% ¼W | 24773-269 |
| | | |
| R6 | Met film 91Ω 2% ¼W | 24773-248 |
| R7 | Met film 24kΩ 2% ¼W | 24773-306 |
| R8 | Met film 240Ω 2% ¼W | 24773-258 |
| R9 | Met film 680Ω 2% ¼W | 24773-269 |
| | | |
| R11 | Met film 91Ω 2% ¼W | 24773-248 |
| R12 | Met film 24kΩ 2% ¼W | 24773-306 |
| R13 | Met film 240Ω 2% ¼W | 24773-258 |
| R14 | Met film 680Ω 2% ¼W | 24773-269 |
| | | |
| R16 | Met film 68Ω 2% ¼W | 24773-245 |
| R17 | Met film 620Ω 2% ¼W | 24773-268 |
| R18 | Met film 560Ω 2% ¼W | 24773-267 |
| R19 | Cerm Var 100Ω 10% ½W | 25711-545 |
| R20 | Met film 560Ω 2% ¼W | 24773-267 |
| R21 | Cerm Var 1kΩ 10% ½W | 25711-544 |
| R22 | Met film 390Ω 2% ¼W | 24773-263 |
| R23 | Met film 3.3kΩ 2% ¼W | 24773-285 |
| R24 | Met film 220Ω 270 ¼W | 24773-257 |
| R25 | Met film 6.8kΩ 2% ¼W | 24773-293 |
| R26 | Met film 430Ω 2% ¼W | 24773-264 |
| R27 | Met film 10kΩ 2% ¼W | 24773-297 |
| R28 | Met film 10kΩ 2% ¼W | 24773-297 |
| R29 | Met film 10kΩ 2% ¼W | 24773-297 |
| R30 | Met film 10kΩ 2% ¼W | 24773-297 |
| R31 | Met film 10kΩ 2% ¼W | 24773-297 |
| R32 | Met film 10kΩ 2% ¼W | 24773-297 |
| R33 | Met film 10kΩ 2% ¼W | 24773-297 |
| R34 | Met film 10kΩ 2% ¼W | 24773-297 |
| R35 | Met film 10kΩ 2% ¼W | 24773-297 |
| R36 | Met film 10kΩ 2% ¼W | 24773-297 |
| R37 | Met film 10kΩ 2% ¼W | 24773-297 |
| R38 | Met film 10kΩ 2% ¼W | 24773-297 |
| R39 | Met film 10kΩ 2% ¼W | 24773-297 |
| R40 | Met film 10kΩ 2% ¼W | 24773-297 |
| R41 | Met film 10kΩ 2% ¼W | 24773-297 |
| R42 | Met film 10kΩ 2% ¼W | 24773-297 |
| R43 | Met film 10kΩ 2% ¼W | 24773-297 |
| R44 | Met film 10kΩ 2% ¼W | 24773-297 |
| R45 | Met film 10kΩ 2% ¼W | 24773-297 |
| R46 | Met film 10kΩ 2% ¼W | 24773-297 |
| R47 | Met film 10kΩ 2% ¼W | 24773-297 |
| R48 | Met film 10kΩ 2% ¼W | 24773-297 |
| R49 | Met film 10kΩ 2% ¼W | 24773-297 |
| R50 | Met film 10kΩ 2% ¼W | 24773-297 |
| R51 | Met film 10kΩ 2% ¼W | 24773-297 |
| R52 | Met film 10kΩ 2% ¼W | 24773-297 |
| R53 | Met film 10kΩ 2% ¼W | 24773-297 |
| R54 | Met film 10kΩ 2% ¼W | 24773-297 |
| | | |
| TR1 | Transistor BFY 90 | 28452-157 |
| TR2 | Transistor BFY 90 | 28452-157 |
| TR3 | Transistor BFY 90 | 28452-157 |
| TR4 | Transistor BSX 20 | 28452-197 |

## Unit A2

*When ordering, prefix circuit reference with A2*

| | | |
|---|---|---|
| | Complete board | 44827-304 |
| C1 | Plas 0.01μF 10% 100V | 26582-211 |
| C2 | Plas 0.047μF 10% 250V | 26582-206 |
| C3 | Plas 0.01μF 10% 250V | 26582-202 |
| C4 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C5 | Elec 4.7μF -20+100% 63V | 26415-801 |
| C6 | Plas 0.1μF 10% 100V | 26582-211 |
| C7 | Plas 0.0012μF 2% 125V | 26516-512 |

*For symbols and abbreviations see introduction to this chapter*

| Circuit reference | Description | M.I. code |
|---|---|---|
| C8 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C9 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C10 | Plas 0.0068μF 2% 125V | 26516-924 |
| C11 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C12 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C13 | Elec 4.7μF -20+100% 63V | 26415-801 |
| C14 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C15 | Plas 0.022μF 10% 250V | 26582-204 |
| C16 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C17 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C18 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C19 | Plas 18pF ±2pF 125V | 26516-028 |
| C20 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C21 | Plas 1.0μF 10% 63V | 26582-414 |
| C22 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C23 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C24 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C25 | Cer 0.1μF -25+50% 30V | 26383-031 |
| C26 | Elec 470μF -20+100% 10V | 26415-821 |
| C27 | Plas 0.1μF 10% 100V | 26582-211 |
| C28 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C29 | Elec 220μF -20+100% 10V | 26415-817 |
| C30 | Plas 0.002μF 10% 250V | 26582-204 |
| C31 | Plas 0.0012μF 2% 125V | 26516-512 |
| C32 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C33 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C34 | Plas 0.1μF 10% 100V | 26582-211 |
| C35 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C36 | Plas 0.047μF 10% 250V | 26582-206 |
| C37 | Plas 150pF ±2pF 125V | 26516-287 |
| C38 | Plas 100pF ±2pF 125V | 26516-241 |
| C39 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C40 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C41 | Cer 0.01μF -20+80% 100V | 26383-055 |
| C42 | Plas 820pF ±2pF 125V | 26516-462 |
| C43 | Elec 22μF -20+100% 25V | 26415-805 |
| C44 | Cer 0.01μF -20+80% | 26383-055 |
| C45 | Cer 0.01μF -20+80% | 26383-055 |
| C46 | Plas 0.1μF 10% 100V | 26582-211 |
| C47 | Plas 0.33μF 10% 100V | 26582-213 |
| C48 | Plas 150pF ±2pF 125V | 26516-287 |
| C49 | Cer 0.001μF -20+80% 500V | 26383-242 |
| C50 | Elec 470μF -20+100% 10V | 26415-821 |
| D1 | Diode Var carb BB105A | 28381-096 |
| D2 | Diode Zener Z5B5-1 | 28371-403 |
| D3 | Diode 1N 4148 | 28336-676 |
| IC1 | Monostable | 28468-303 |
| IC2 | Monostable | 28468-303 |
| IC3 | Monostable | 28468-303 |
| IC4 | Decade counter (2-5-10) | 28464-002 |
| IC5 | Decade counter (2-5-10) | 28464-002 |
| IC6 | Decade counter (2-5-10) | 28464-002 |
| IC7 | Decade counter (2-5-10) | 28464-002 |
| IC8 | Dual 4 input NAND gate | 28466-324 |
| IC9 | Monostable | 28468-303 |
| IC10 | Monostable | 28468-303 |
| IC11 | Monostable | 28468-303 |
| IC12 | Dual JK bistable | 28462-013 |
| IC13 | Dual JK bistable | 28462-013 |
| IC14 | Monostable | 28468-303 |
| IC15 | Decade counter (2-5-10) | 28464-002 |
| IC16 | Decade counter (2-5-10) | 28464-002 |
| IC17 | Decade counter (2-5-10) | 28464-002 |
| IC18 | Decade counter (2-5-10) | 28464-002 |
| IC19 | Dual 4 input NAND gate | 28466-324 |
| L1 | Inductor assembly | 44278-217 |
| L2 | RF choke 330μH | 23642-564 |

*For symbols and abbreviations see introduction to this chapter*

| Circuit reference | Description | M.I. code | Circuit reference | Description | M.I. code |
|---|---|---|---|---|---|
| R1 | Met film 100kΩ 2% ¼W | 24773-321 | R37 | Met film 22kΩ 2% ¼W | 24773-305 |
| R2 † | Met film 6.8kΩ 2% ¼W | 24773-293 | R38 | Met film 1kΩ 2% ¼W | 24773-321 |
| R3 | Cerm Var 2.2kΩ 10% ½W | 25711-547 | R39 | Met film 470Ω 2% ¼W | 24773-265 |
| R4 | Met film 2.2kΩ 2% ¼W | 24773-281 | R40 | Met film 1.2kΩ 2% ¼W | 24773-275 |
| R5 | Cerm Var 2.2kΩ 10% ½W | 25711-547 | R41 | Met film 3.9kΩ 2% ¼W | 24773-287 |
| R6 | Met film 2.2kΩ 2% ¼W | 24773-281 | R42 | Met ox 2.7kΩ 2% ½W | 24573-083 |
| R7 | Met film 22kΩ 2% ¼W | 24773-305 | R43 | Met film 22kΩ 2% ¼W | 24773-305 |
| R8 | Met film 1kΩ 2% ¼W | 24773-273 | R44 | Met film 22kΩ 2% ¼W | 24773-305 |
| R9 | Met film 820Ω 2% ¼W | 24773-271 | R45 | Met film 22kΩ 2% ¼W | 24773-305 |
| R10 | Met film 1.8kΩ 2% ¼W | 24773-279 | R46 | Met film 10kΩ 2% ¼W | 24773-321 |
| R11 | Met film 3.9kΩ 2% ¼W | 24773-287 | R47 | Met film 3.9kΩ 2% ¼W | 24773-287 |
| R12 | Met ox 2.7kΩ 2% ½W | 24573-083 | R48 | Met ox 2.7kΩ 2% ½W | 24573-083 |
| R13 | Met ox 560kΩ 2% ½W | 24573-139 | R49 | Met film 100Ω 2% ¼W | 24773-249 |
| R14 | Met film 22kΩ 2% ¼W | 24773-305 | R50 | Met film 22kΩ 2% ¼W | 24773-321 |
| R15 | Met film 22kΩ 2% ¼W | 24773-305 | R51 | Met film 3.3kΩ 2% ¼W | 24773-285 |
| R16 | Met film 6.8kΩ 2% ¼W | 24773-293 | R52 | Met film 1kΩ 2% ¼W | 24773-273 |
| R17 | Met ox 4.7kΩ 2% ½W | 24573-089 | R53 | Met film 1kΩ 2% ¼W | 24773-273 |
| R18 | Met ox 560kΩ 2% ½W | 24573-139 | R54 | Met film 82Ω 2% ¼W | 24773-247 |
| R19 | Met film 3.3kΩ 2% ¼W | 24773-285 | | | |
| R20 | Met film 10kΩ 2% ¼W | 24773-297 | | | |
| R21 | Met film 4.7kΩ 2% ¼W | 24773-289 | TR1 | Transistor BC 107 | 28455-437 |
| R22 | Met film 820Ω 2% ¼W | 24773-271 | TR2 | Transistor BF 244B | 28459-011 |
| R23 | Met film 470Ω 2% ¼W | 24773-265 | TR3 | Transistor BC 107 | 28455-437 |
| R24 | Met film 4.7kΩ 2% ¼W | 24773-289 | TR4 | Transistor BC 107 | 28455-437 |
| R25 | Met ox 620kΩ 2% ½W | 24573-140 | TR5 | Transistor BF 244B | 28459-011 |
| R26 | Met film 120kΩ 2% ¼W | 24773-323 | TR6 | Transistor BC 107 | 28455-437 |
| R27 | Met film 120kΩ 2% ¼W | 24773-323 | TR7 | Transistor BF 244B | 28459-011 |
| R28 | Met film 820Ω 2% ¼W | 24773-271 | TR8 | Transistor BF 244B | 28459-011 |
| R29 | Met film 470Ω 2% ¼W | 24773-265 | TR9 | Transistor BSX 20 | 28452-197 |
| R30 | Met film 10kΩ 2% ¼W | 24773-297 | TR10 | Transistor BSX 20 | 28452-197 |
| R31 | Met film 4.7kΩ 2% ¼W | 24773-289 | TR11 | Transistor BSX 20 | 28452-197 |
| R32 | Met film 22kΩ 2% ¼W | 24773-305 | TR12 | Transistor BC 107 | 28455-437 |
| R33 | Met film 1kΩ 2% ¼W | 24773-273 | TR13 | Transistor BF 244B | 28459-011 |
| R34 | Met film 100kΩ 2% ¼W | 24773-321 | TR14 | Transistor BC 107 | 28455-437 |
| R35 † | Met film 6.8kΩ 2% ¼W | 24773-293 | TR15 | Transistor BC 107 | 28455-437 |
| R36 | Cerm Var 2.2kΩ 10% ½W | 25711-547 | TR16 | Transistor BF 244B | 28459-011 |

*For symbols and abbreviations see introduction to this chapter*

| Circuit reference | Description | M.I. code |
|---|---|---|
| TR17 | Transistor BC 107 | 28455-437 |
| TR18 | Transistor BF 244B | 28459-011 |
| TR19 | Transistor BF 244B | 28459-011 |
| X01 | Crystal unit 10.02 MHz | 28311-774 |
| X02 | Crystal oscillator 5 MHz | 28313-865 |

## Unit A3

*When ordering, prefix circuit reference with A3*

| | | |
|---|---|---|
| | Complete board | 44827-305 |
| APC1 | Analogue photo coupler | 44990-097 |
| C1 | Elec 47μF -20+100% 40V | 26415-810 |
| C2 | Plas 1μF 10% 100V | 26582-217 |
| D1 | Diode 1N 4148 | 28336-676 |
| D3 | Diode 1N 4148 | 28336-676 |
| D4 | Diode 1N 4148 | 28336-676 |
| R1 | Met film 3.9kΩ 2% ¼W | 24773-287 |
| R2 | Met film 220Ω 2% ¼W | 24773-257 |
| R3 | Met film 68Ω 2% ¼W | 24773-245 |
| R4 | Met film 15kΩ 2% ¼W | 24773-301 |
| R5 | Met film 62kΩ 2% ¼W | 24773-316 |
| R6 | Met film 4.3kΩ 2% ¼W | 24773-288 |
| R7 | Met film 4.7kΩ 2% ¼W | 24773-289 |
| R8 | Met film 4.7kΩ 2% ¼W | 24773-289 |
| R9 | Met film 100kΩ 2% ¼W | 24773-321 |
| R10 | Met film 20kΩ 2% ¼W | 24773-304 |
| R11 | Met film 39kΩ 2% ¼W | 24773-311 |
| R12 | Met film 100kΩ 2% ¼W | 24773-321 |
| R13* † | Met film 330 K 2% ¼W | 24773-261 |
| R14 | Met film 20kΩ 2% ¼W | 24773-304 |
| R15 | Met film 39kΩ 2% ¼W | 24773-311 |
| R16 | Met film 100kΩ 2% ¼W | 24773-321 |
| R17* † | Met film 330 K 2% ¼W | 24773-261 |
| TR1 | Transistor BCY 71 | 28435-235 |
| TR2 | Transistor BCY 71 | 28435-235 |
| TR3 | Transistor BC 109 | 28452-777 |
| TR4 | Transistor BC 109 | 28452-777 |
| TR5 | Transistor BCY 71 | 28435-235 |
| TR6 | Transistor BC 109 | 28452-777 |

* Only one SIC resistor, either R13 or R17, is required to be changed to obtain balance - see Sect. 4.7.12.

## Unit A4

*When ordering, prefix circuit reference with A4*

| | | |
|---|---|---|
| | Complete board | 44827-306 |
| C1 | Elec 4.7μF -20+100% 63V | 26415-801 |
| C2 | Elec 470μF -20+100% 25V | 26415-822 |
| D1 | Diode 1N 4004 | 28357-028 |
| D2 | Diode 1N 4004 | 28357-028 |
| D3 | Diode 1N 4004 | 28357-028 |
| D4 | Diode 1N 4004 | 28357-028 |
| D5 | Diode 1N 5401 | 28355-723 |
| D6 | Diode 1N 5401 | 28355-723 |
| D7 | Diode 1N 5401 | 28355-723 |
| D8 | Diode 1N 5401 | 28355-723 |
| D9 | Diode 1N 4004 | 28357-028 |
| D10 | Diode 1N 4004 | 28357-028 |
| D11 | Diode 1N 4004 | 28357-028 |
| D12 | Diode 1N 4004 | 28357-028 |
| D13 | Diode Zener Z5B18 | 28372-583 |

*For symbols and abbreviations see introduction to this chapter*

| Circuit reference | Description | M.I. code |
|---|---|---|
| IC1 | Operational amplifier μA 741 | 28461-304 |
| R1 | Met ox 390Ω 2% ½W | 24573-063 |
| R2 | Met ox 330Ω 2% ½W | 24573-061 |
| R3 | WW Var 47Ω 10% 1W | 25811-011 |
| R4 | Met ox 470Ω 2% ½W | 24573-065 |
| R5 | Met ox 10kΩ 2% ½W | 24573-097 |
| R6 | Met ox 10kΩ 2% ½W | 24573-097 |

**Miscellaneous items**

| | |
|---|---|
| Cap and chain BNC | 23443-591 |
| Cap and chain TNC | 23444-898 |
| Case clip (four) | 23315-098 |

| Circuit reference | Description | M.I. code |
|---|---|---|
| Frequency switch (seven) | | |
| | Knob | 22318-333 |
| | Knob cap | 22318-334 |
| | Dial | 22318-335 |
| | Stator | 22318-336 |
| Carrying handle | | |
| | Handle liner | 22315-572 |
| | Handle section | 22315-575 |
| | Handle end cap (two) | 22315-573 |
| Jack TNC (SKB) | | 23444-742 |
| Mains connector (PLA) | | 23423-159 |
| Plastic stand (two rear of case) | | 22315-663 |
| Socket BNC (SKC SKD) | | 23443-443 |

For symbols and abbreviations see introduction to this chapter

# Index to Units

| *Unit number* | *M.I. code* | *Description* | *Circuit diagram Fig.* | *Parts list page* |
|---|---|---|---|---|
| A0 | | Chassis and panel components | 7.1 to 7.4 | 24 |
| A1 | 44827-303 | Input amplifier and diode shaper.<br>Prescaler and amplifier. | 7.1 | 24 |
| | | Variable ratio frequency dividers VRD1 and VRD2. | 7.2 | 24 |
| A2 | 44827-304 | 5 MHz crystal controlled oscillator and associated dividers XO2 and FD2.<br>10 MHz voltage tuned crystal oscillator and associated dividers XO1 and FD1.<br>Ramp generators RG1 and RG2.<br>Phase detectors PD1 and PD2.<br>Sample and hold drivers DR1 and DR2.<br>Lock indicator circuits. | 7.3 | 26 |
| A3 | 44827-305 | Interface circuits | 7.1 | 29 |
| A4 | 44827-306 | Power supplies | 7.4 | 29 |

Chapter 7

# Circuit diagrams

## Circuit notes

1. COMPONENT VALUES

Resistors : No suffix = ohms, k = kilohms, M = megohms.

Capacitors : No suffix = microfarads, p = picofarads.

† value selected during test, nominal value shown.

2. VOLTAGES

Shown in italics adjacent to the point to which the measurement refers. See section 4.1 for conditions.

3. SYMBOLS

arrow indicates clockwise rotation of of knob.

RANGE etc., external front or rear panel marking.

tag on printed board.

other tag.

preset control.

A2 unit identification number.

These symbols are used to identify branches of the power supply circuitry but have no particular physical reality on the printed boards.

A point marked with this symbol is connected to and receives power from point marked with this symbol

A

4. CIRCUIT REFERENCES

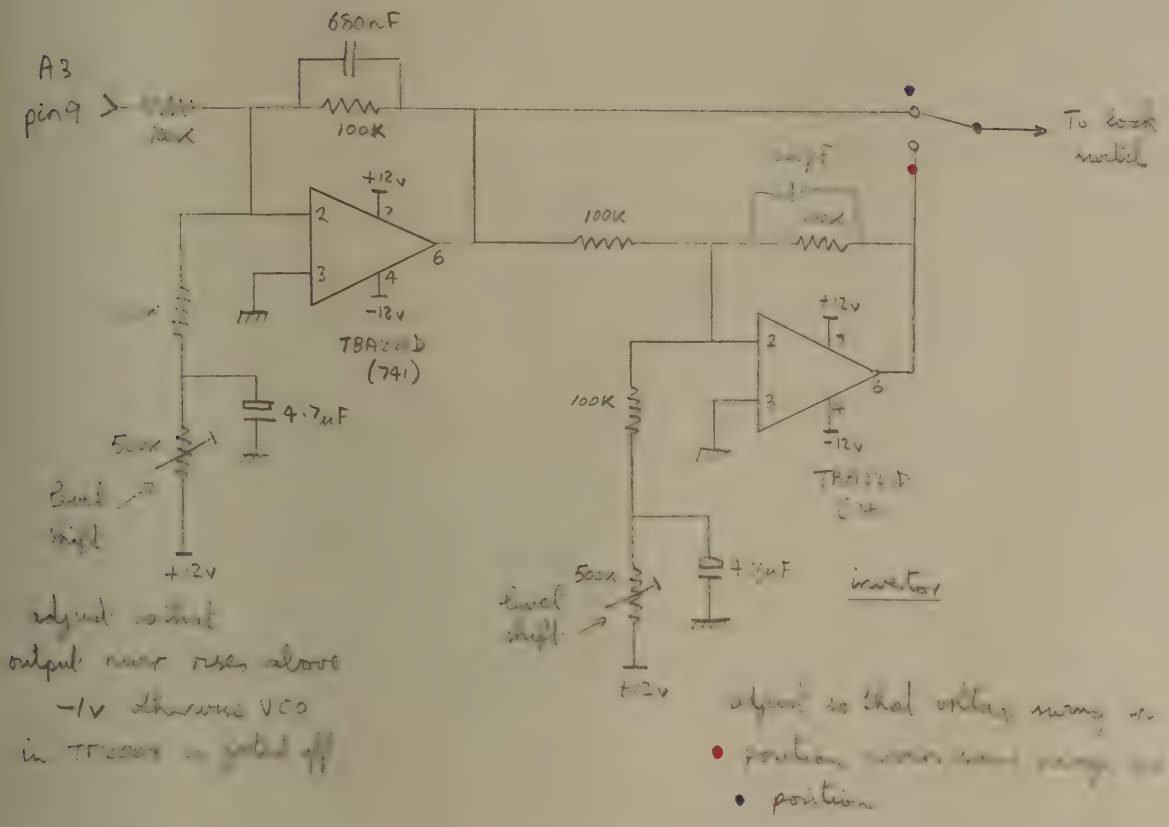
These are, in general, given in abbreviated form - see Chapter 6.

5. SWITCHES

Rotary switches are drawn schematically.
Letters indicate control knob settings.
1F = 1st section (front panel), front
1B = 1st section, back
2F = 2nd section, front
etc.

Modification on TF2171 ser No 117006/24 B211249

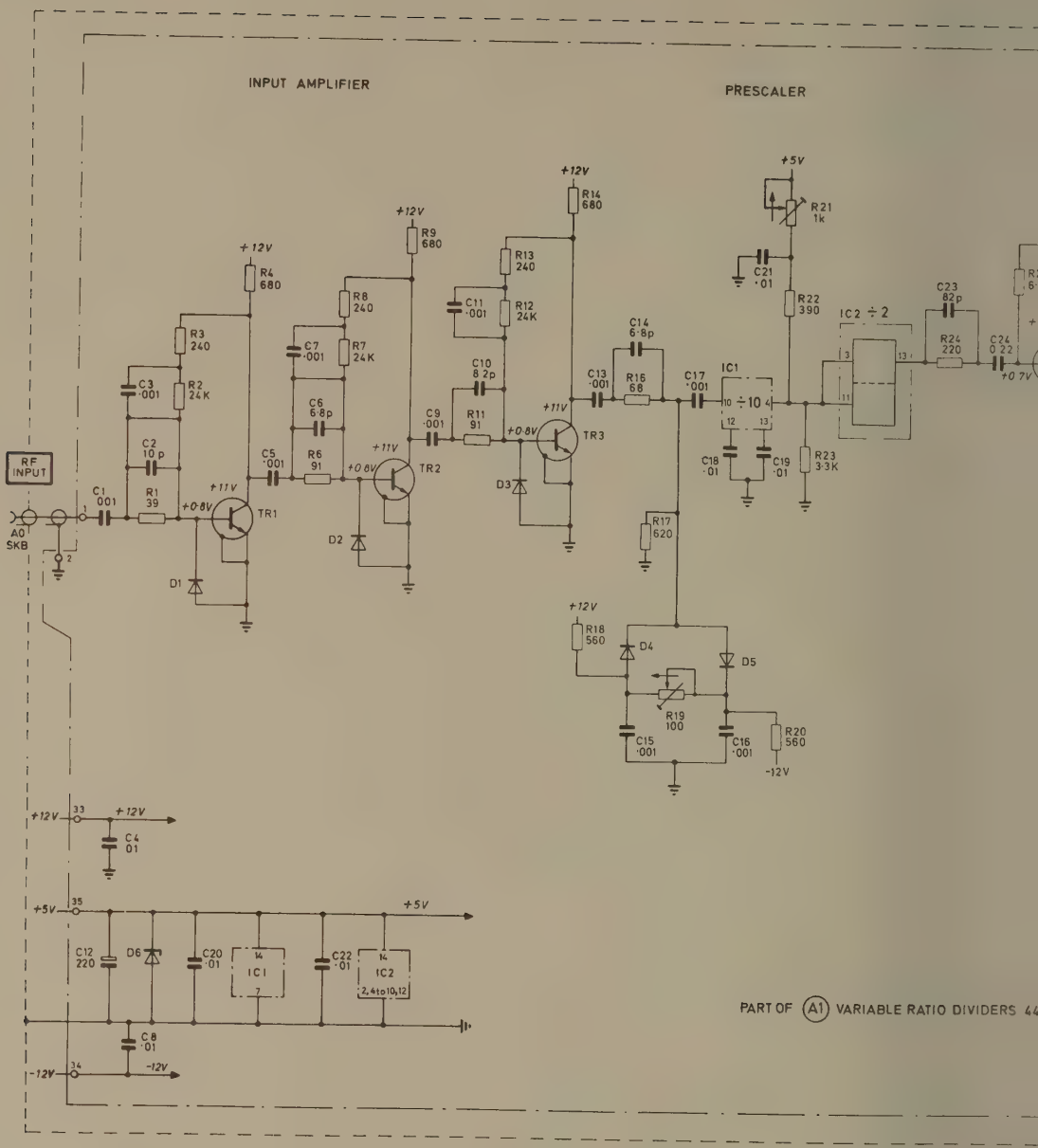
To be used with TF2008 signal generator




The TF2171 can only be used to lock the TF2008 at frequencies between 5 and 500 MHz!

decoupling in RF fields box required to reduce spikes getting into control voltage line.

Power supply smoothing network provided by R50 1K & reduces 5v to +2.5v rail.


INPUT AMPLIFIER
PRESCALER
RF INPUT
A0 SKB
+12V
+5V
-12V
+11V
+0·8V
TR1
TR2
TR3
D1
D2
D3
D4
D5
D6
IC1 ÷10
IC2 ÷2
R1 39
R2 24K
R3 240
R4 680
R6 91
R7 24K
R8 240
R9 680
R11 91
R12 24K
R13 240
R14 680
R16 68
R17 620
R18 560
R19 100
R20 560
R21 1k
R22 390
R23 3·3K
R24 220
C1 ·001
C2 10p
C3 ·001
C4 ·01
C5 ·001
C6 6·8p
C7 ·001
C8 ·01
C9 ·001
C10 8·2p
C11 ·001
C12 220
C13 ·001
C14 6·8p
C15 ·001
C16 ·001
C17 ·001
C18 ·01
C19 ·01
C20 ·01
C21 ·01
C22 ·01
C23 82p
C24 0·22
+0·7V
PART OF (A1) VARIABLE RATIO DIVIDERS 44

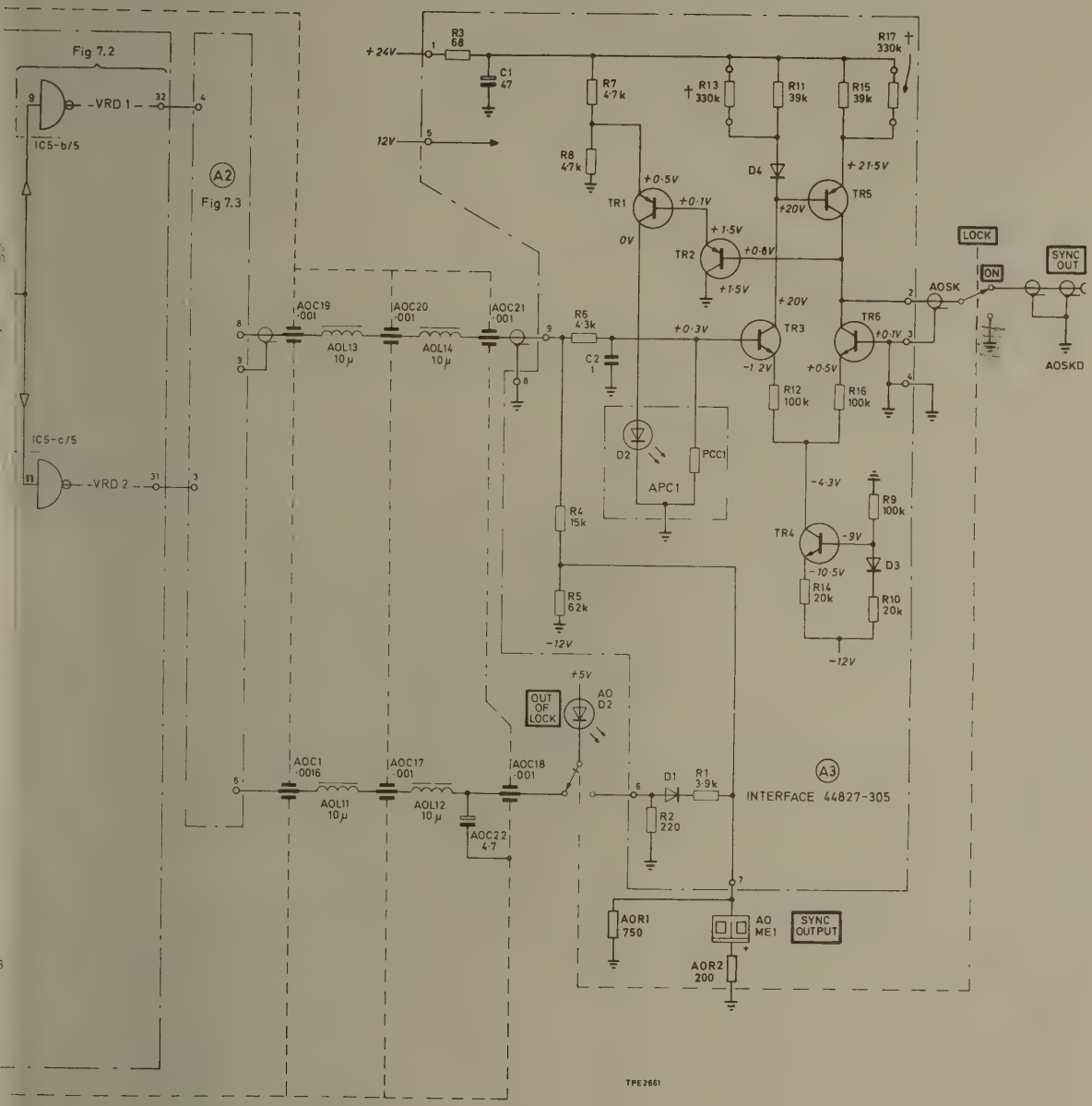
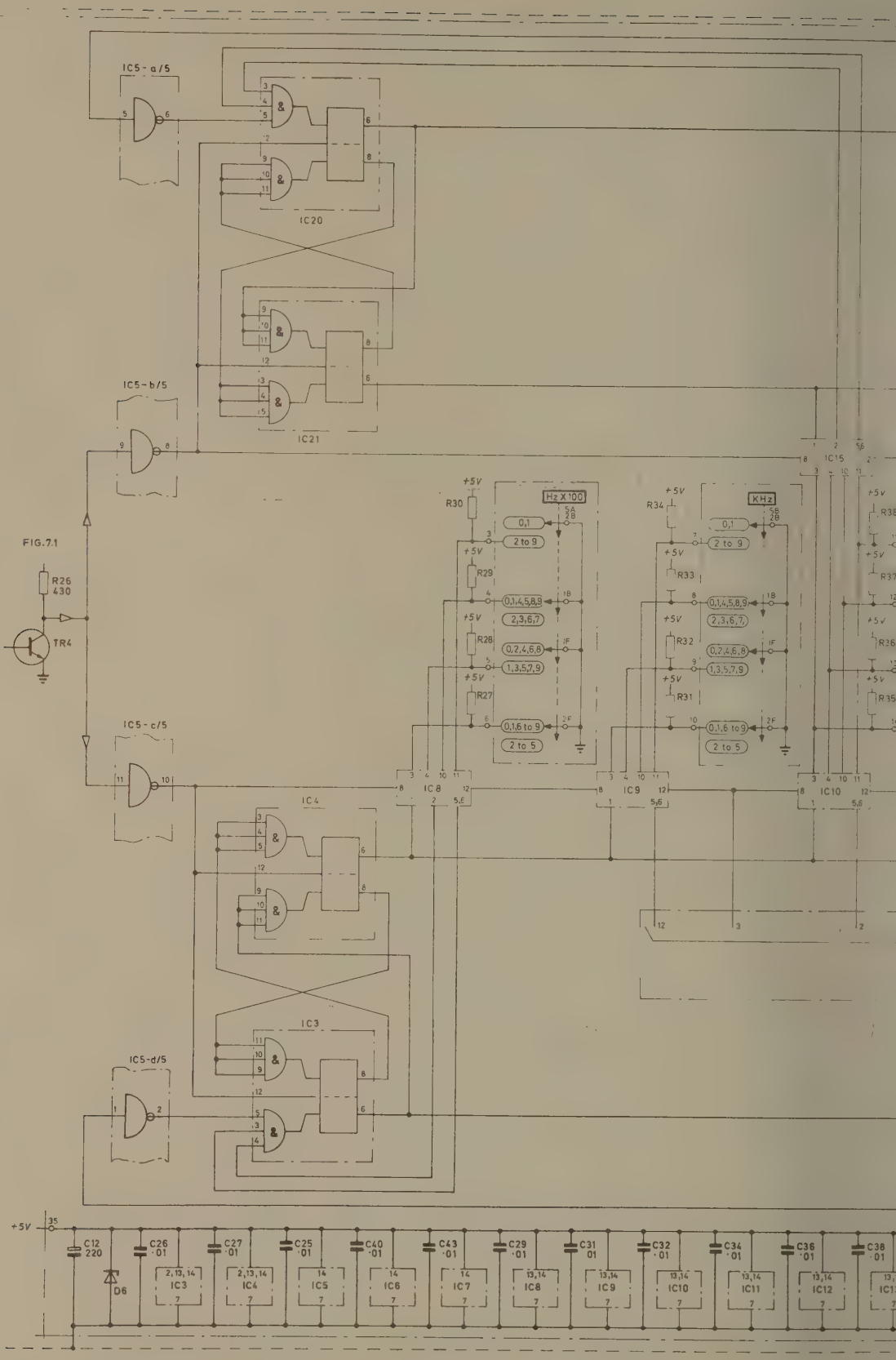



*Fig. 7.1 Input amplifier, prescaler and interface*


IC5-a/5
IC20
IC5-b/5
IC21
IC15
FIG.7.1
R26
430
TR4
+5V
R30
Hz X 100
0,1
2 to 9
R29
0,1,4,5,8,9
2,3,6,7
R28
0,2,4,6,8
1,3,5,7,9
R27
0,1,6 to 9
2 to 5
R34
KHz
R33
R32
R31
IC5-c/5
IC4
IC3
IC5-d/5
IC8
IC9
IC10
D6
C12
220
C26
·01
C27
·01
C25
·01
C40
·01
C43
·01
C29
·01
C31
01
C32
·01
C34
·01
C36
·01
C38
·01
IC5
IC6
IC7
IC11
IC12

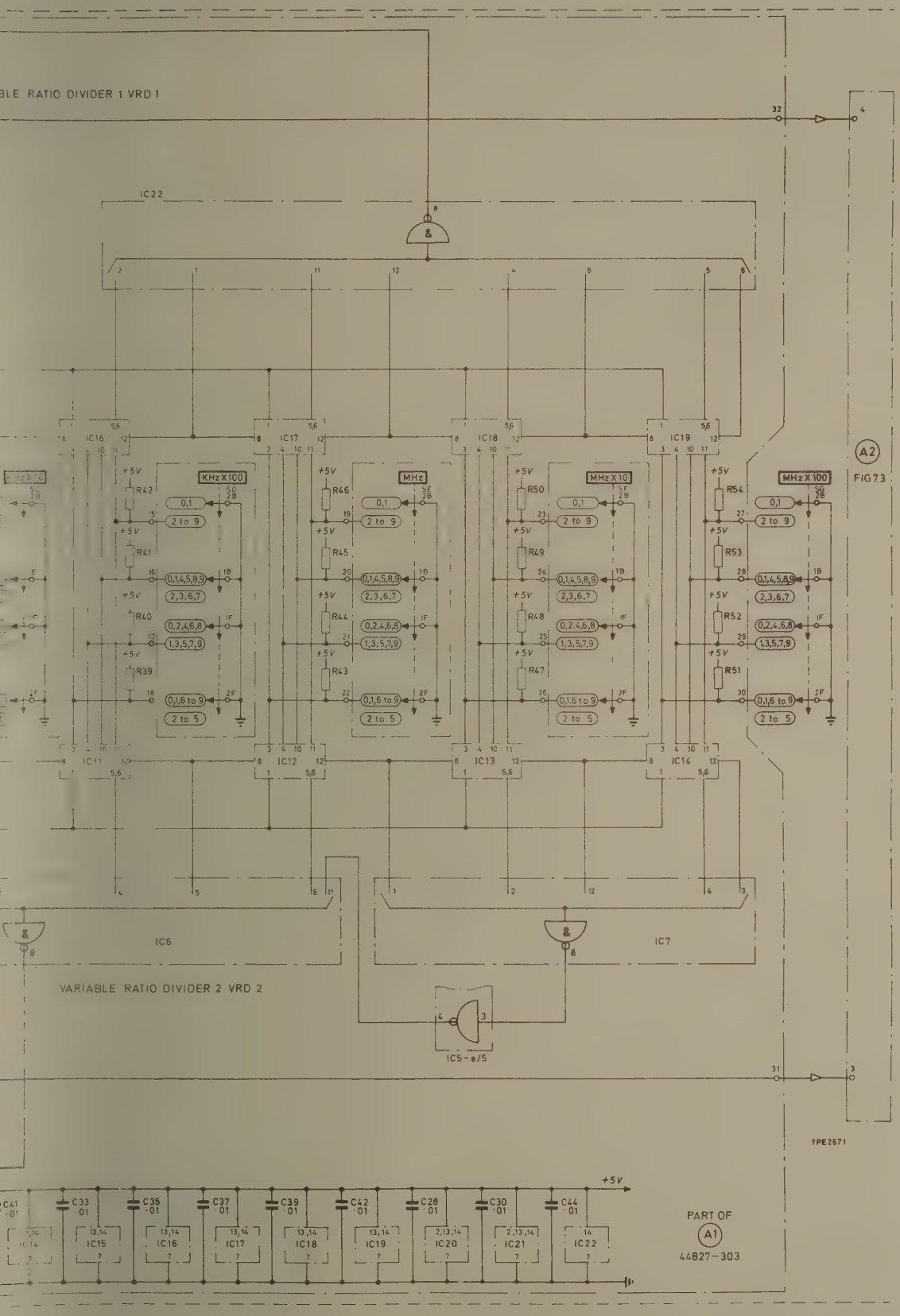
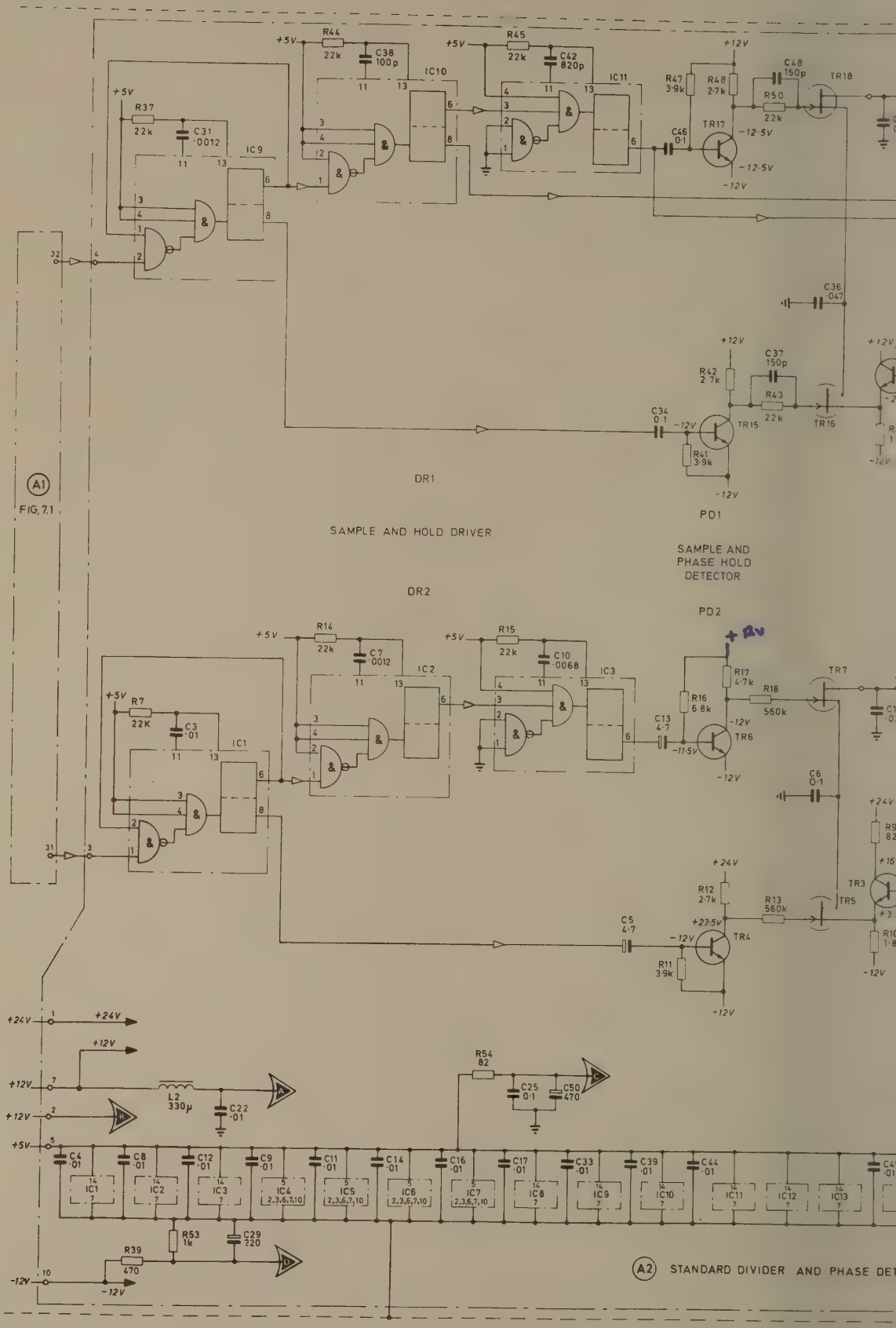



*Fig. 7.2 Variable ratio dividers*


DR1
SAMPLE AND HOLD DRIVER
PD1
SAMPLE AND PHASE HOLD DETECTOR
DR2
PD2
A1
FIG. 7.1
A2 STANDARD DIVIDER AND PHASE DET
+5V
+12V
+24V
-12V
IC1
IC2
IC3
IC4
IC5
IC6
IC7
IC8
IC9
IC10
IC11
IC12
IC13
TR3
TR4
TR5
TR6
TR7
TR15
TR16
TR17
TR18
L2 330µ

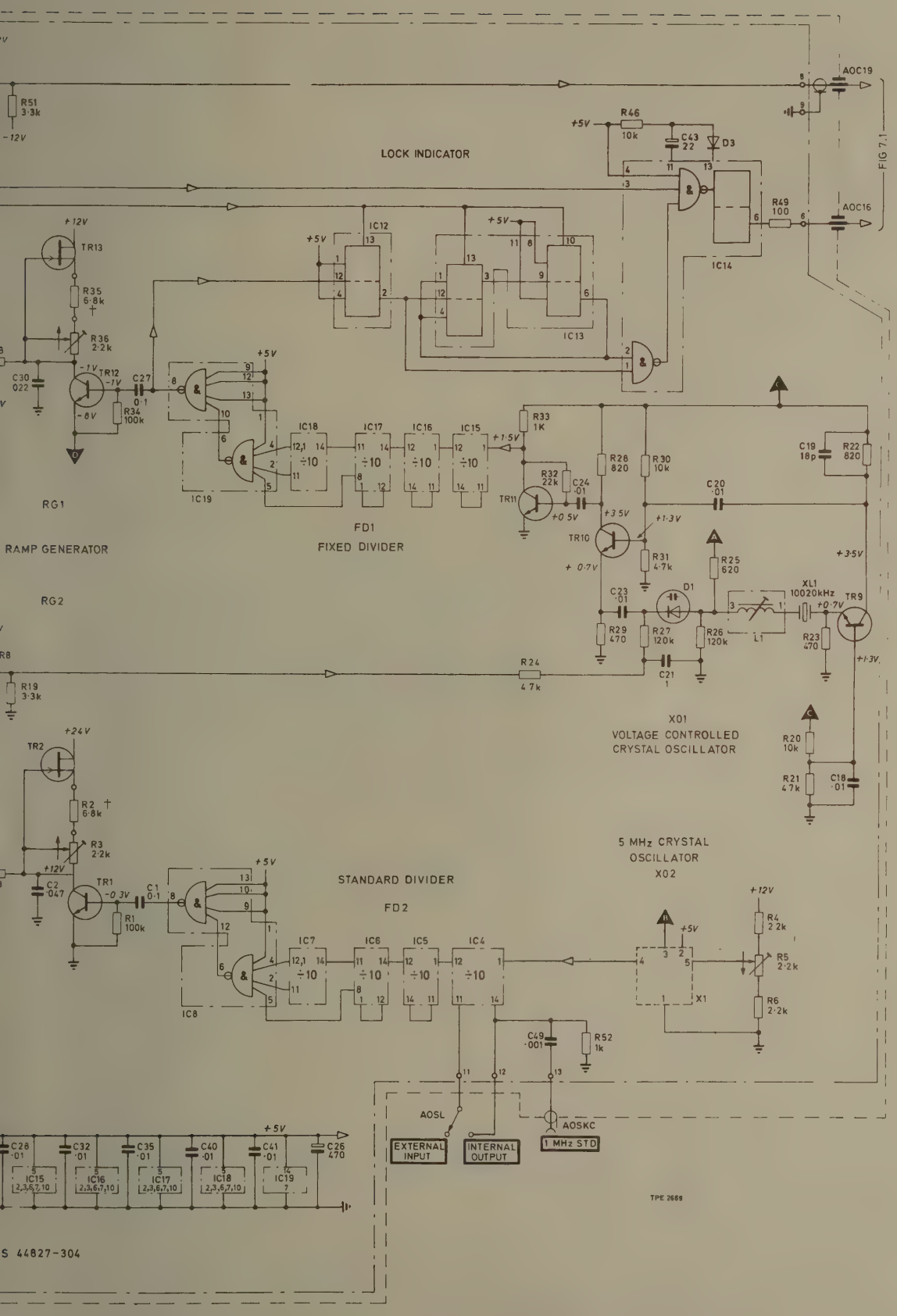
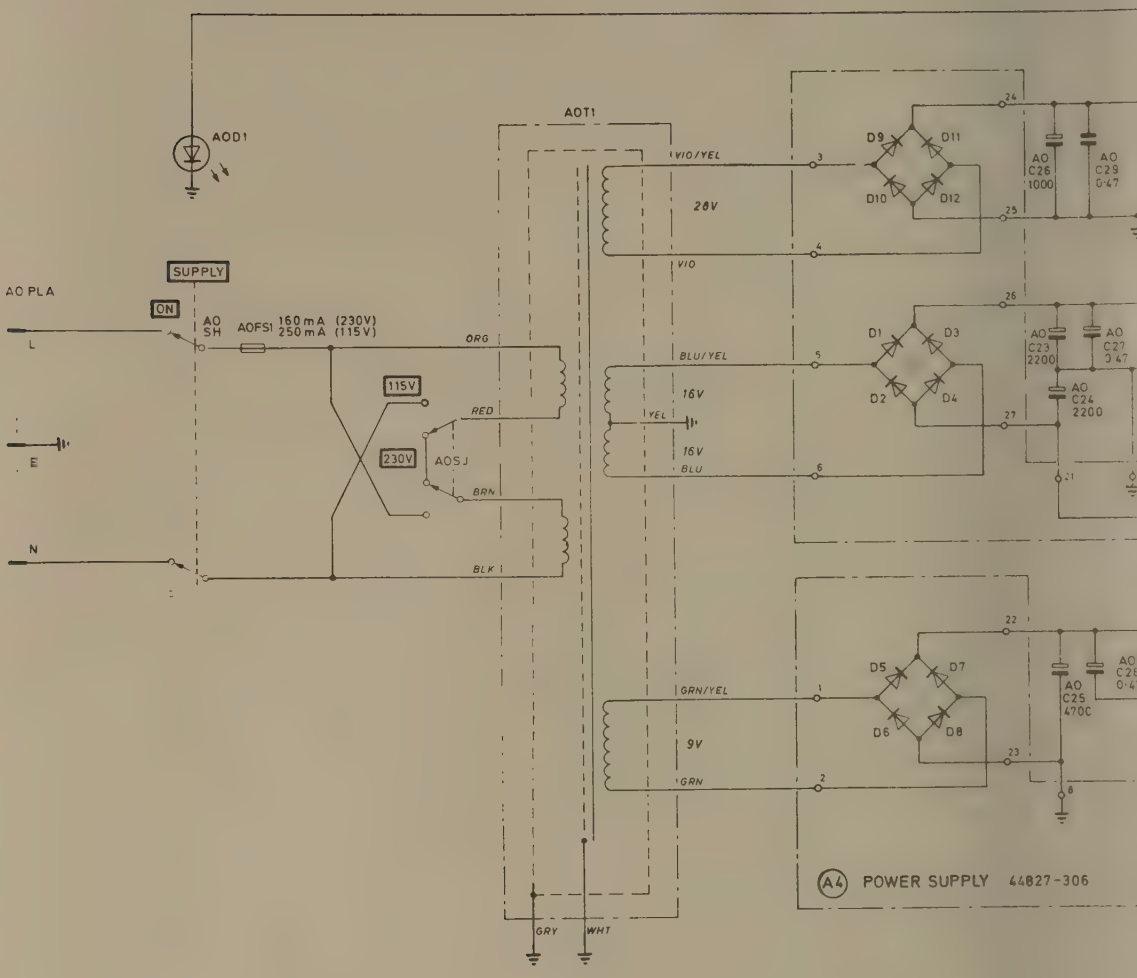



*Fig. 7.3 Standard and fixed dividers and phase detector*


AOD1
AOT1
AO PLA
SUPPLY
ON
L
E
N
AO SH
AOFS1 160 mA (230V) 250 mA (115V)
115V
230V
AOSJ
ORG
RED
BRN
BLK
VIO/YEL
28V
VIO
BLU/YEL
16V
YEL
16V
BLU
GRN/YEL
9V
GRN
GRY
WHT
D9
D11
D10
D12
D1
D3
D2
D4
D5
D7
D6
D8
AO C26 1000
AO C23 2200
AO C24 2200
AO C25 4700
A4 POWER SUPPLY 44827-306

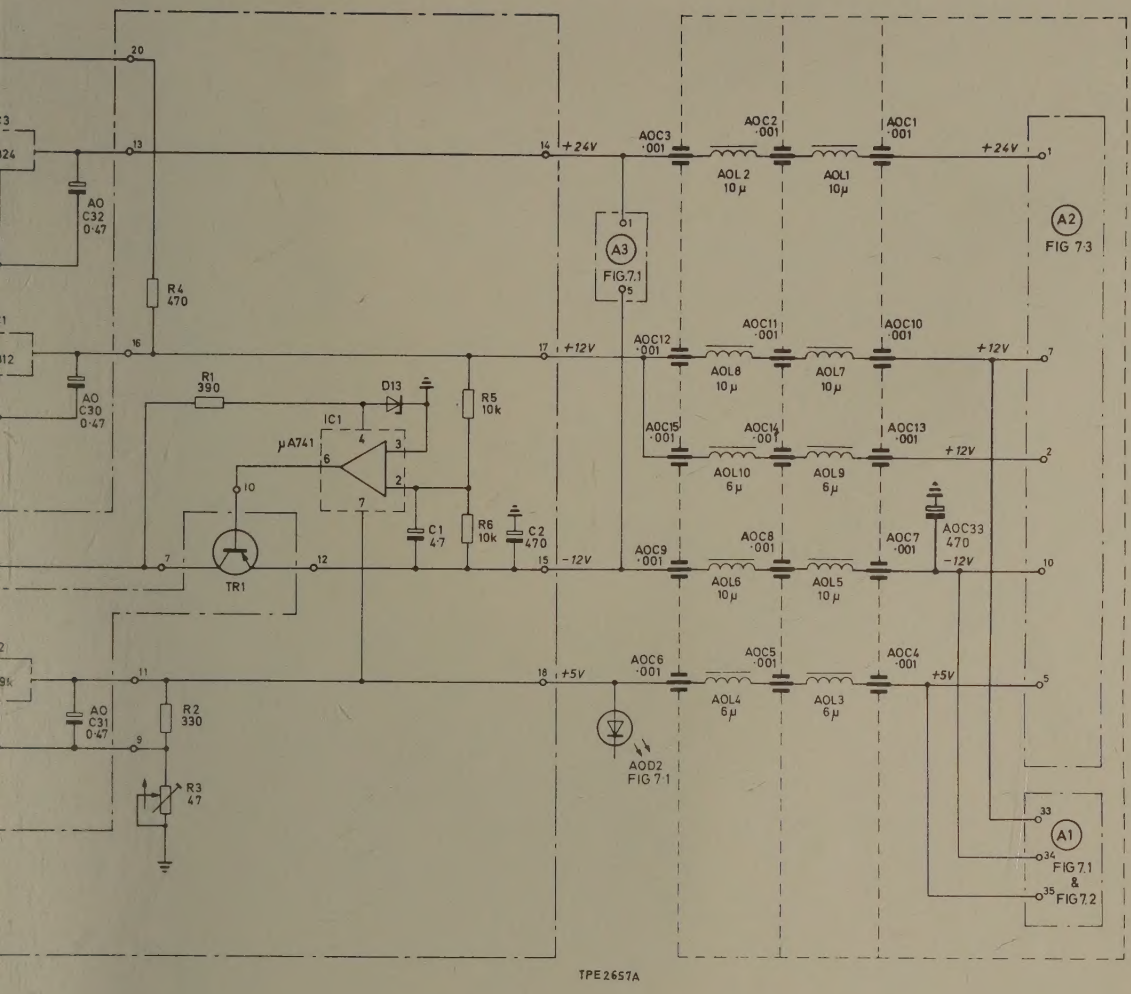



*Fig. 7.4 Power supplies*

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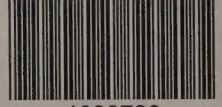

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